6.—A SOIL SURVEY OF AN AREA AT GINGIN, WESTERN AUSTRALIA.[1]

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CONTENTS.

(1) A soil survey of the country in the neighbourhood of Gingin in the district of Swan in Western Australia was undertaken by the Division of Soils of the Council for Scientific and Industrial Research, centred at the Waite Institute of the University of Adelaide, in collaboration with the Department of Agriculture of Western Australia. The field work was carried out by the authors conjointly, assisted by L. C. Lightfoot. The laboratory work, with the exception of portion of the mechanical analyses, which were carried out by H. R. Skewes and G. Parker, was performed by J. S. Hosking.

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I.—SUMMARY.

A soil survey of an area associated with the Cretaceous rocks in the neighbourhood of Gingin in the District of Swan in Western Australia has been made and eleven major soil types recognised and described. The soils fall into five groups:—

1. The Gingin Clay—a rendzina formed on the Gingin chalks. Associated with this are the Ballingah sandy loam, formed on green sand, and the Mt. Pleasant sand.
2. The Whakea sand and related types formed on the ferruginous sandstones above and below the chalk.
3. The Cheriton gravelly sand associated with an occurrence of laterite.
4. The Muchea sand of the coastal plain.
5. Other soils, including the Minjil sand, undifferentiated alluvial soils, etc.

Chemical and mechanical analyses of soil samples representative of the types have been carried out and the results fully discussed.

The agricultural development of the area has been along lines of stock raising. A problem of live-stock associated with the area, enzootic ataxia, has also been discussed.

II.—GENERAL DESCRIPTION OF THE AREA.

(1)—*Location and area surveyed.*

Gingin (31° 21′ south latitude 115° 54′ east longitude) is a small township about 50 miles north of Perth on the Midland Company's railway line to Geraldton. It is situated on the banks of the Gingin Brook where it emerges from the Darling Plateau on to the Coastal Plain. The area surveyed comprises about 15,500 acres. It extends about four miles to the north, one mile and a half to the south and about two and a half miles on either side of the township. In addition, a reconnaissance was made of the coastal plain country to the west, where a series of soil samples was collected for examination and comparison with those of the main area.

(2)—*Settlement and Present State of Development.*

Gingin is an old established pastoral district renowned for the fattening of sheep and cattle, for which purpose it is most largely used. Difficulties, however, have been experienced in the breeding of stock. The progeny of sheep, mares and cows continuously depastured on this country, become affected with what is popularly known as "rickets." The manifestations vary with the animals affected. The condition developed by lambs has no relation to the disease rickets or rachitis, and has been designated "enzootic ataxia" by Bennetts (1932, 1933, 1935). It is characterised clinically by unthriftiness and anaemia, and pathologically by a degeneration of the nervous tissue. There is also a characteristic inco-ordination of gait. In foals and calves the disease develops quite differently, and has some resemblance to true rickets. It has not yet, however, been studied in detail.

Enzootic ataxia was almost unknown when the country was in its virgin state. It commenced to be a serious economic factor about twenty years ago, and the incidence progressively increased following development and pasture improvement, so much so that at the present time breeding is generally carried out from ewes which are brought from outside sound areas each year. If the ewes are retained for more than one year they are given a change on to sound country for about eight weeks during gestation. Under these conditions the lambs are generally quite healthy. In some cases the incidence of the disease in the progeny of ewes, which have been retained for more than one season on the affected country without change, approaches 100 per cent.

Thoroughbred horses were formerly bred at Gingin, but the increasing occurrence of rickets in foals led to the almost complete abandonment of this pursuit some years ago. The situation has recently been altered as a result of a treatment based on the lead hypothesis, and it is now possible to prevent and cure the disease in foals by the administration of ammonium chloride. Thoroughbred horses are now being bred successfully at Gingin. (Bennetts (1935a) and private communication.)

Calves are also affected by the disease, but trouble can be avoided by giving the cows a change of country or by shifting the young stock when they become affected. Diseased foals and calves immediately improve if moved on to sound country, and the progress of ataxia in a flock is definitely arrested almost immediately if the ewes and lambs are changed to sound country. Lambs which are definitely ataxic, however, very rarely recover completely, although the progress of the disease towards the fatal result may be arrested.

The disease also occurs at Dandarragan and Yatheroo, about 50 miles further north of Gingin, and an important feature common to both areas is the occurrence of rocks of the Cretaceous series which are lithologically similar. It seemed, therefore, that there might be some correlation of the disease with the soils formed from these rocks, and it was with this end in view that the soil survey was made.

The principal crops grown at Gingin are rye, oats, and lupins on the drier soils, and summer fodders on the highly productive alluvial flats. Orange growing, for which Gingin was at one time famous, has, for various economic reasons, practically ceased as an important industry.

(3)—*Climatic Features.*

Complete climatic data for either Gingin or Dandarragan are not available, but rainfall observations have been kept for over 40 years, and show an average annual precipitation of about 30 inches. The figures indicate a distinct seasonal fall, approximately 90 per cent. of the annual precipitation falling in the period May to October. The November-April rainfall period is very dry, averaging only half an inch per month. Rainfall figures for a station on the coastal plain country are also available, although for a much shorter period, and show the same character in the seasonal incidence. The rainfall per wet day is remarkably constant throughout the areas under review, being 0.32 inch at all the stations considered. No temperature records are available for this district. However, the figures for Guildford, some 40 miles to the south, illustrate that the hottest periods coincide with those of least precipitation, and that frosts occur occasionally during the winter and early spring. Rainfall data for Gingin and other centres in the district, together with temperature records for Guildford, are given in Table 1.

Table 1.

TABLE 1a—RAINFALL DATA.

Station.	Years of Records.	Rainfall.																Rain per Rain Day.
		Mean Monthly.												Annual.				
		Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.	Max.*	Min.†	Number of Days.	
Gingin ...	1889–1925	0·28	0·46	0·61	1·03	4·40	6·22	6·13	5·01	3·20	2·34	0·53	0·49	30·70	44·04	12·06	96	0·32
Dandarragan	1897–1925	0·30	0·49	0·59	1·04	3·82	5·43	5·40	4·08	3·14	1·96	0·44	0·45	27·14	52·42	10·33	86	0·32
Yatheroo ...	1885–1929	0·17	0·33	0·64	0·93	3·38	5·13	4·91	4·01	2·91	1·75	0·53	0·38	25·07	39·23	12·12	81	0·31
Beermullah	1917–1925	...	...	...	...	...	...	...	...	...	...	...	...	27·53	38·38	...	86	0·32

* 1917 † 1914 (year of drought).

TABLE 1b—TEMPERATURE DATA FOR GUILDFORD, 1900–1931.

Month.	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Mean Maximum	88·7	88·9	85·5	79·7	79·6	65·3	63·7	65·7	68·6	72·0	79·6	85·4	76·1
Mean Minimum	61·8	61·9	59·5	55·3	50·1	47·0	45·1	46·1	48·3	50·7	55·2	59·2	53·3
Highest Recorded	109·9	113·0	110·0	103·2	92·6	84·0	78·1	81·6	93·0	99·0	108·8	109·6	113·0
Lowest Recorded	43·0	42·0	42·1	36·5	29·2	30·0	29·8	30·2	35·0	35·0	39·3	42·0	29·2

(4)—*Physiography and Geology.*

(a)—*Physiography.*

The Gingin area consists physiographically of four major features:—

1. The plateau country and its outliers ranging from about 500 to 700 feet above sea level.
2. The plateau slopes and escarpments.
3. The Gingin Brook valley and the valley of Moonda and Wowra Brooks. These formations range in elevation from 300 to 400 feet.
4. The coastal plain country which ranges from about 250 to 300 feet above sea level in the area surveyed.

The present topography is the result of erosion by the Gingin Brook which flows right through the area and which has been assisted in its work of land sculpture by numerous small tributaries. The present state of the land is that of a much dissected plateau the topography of which still presents a very juvenile aspect. The Gingin Brook rises in the north-eastern part of the area and flows in a south-westerly direction through a steep-sided broad valley which has been cut through the ferruginous sandstones and chalky limestone of the Cretaceous series. North-east of Gingin townsite the course of the brook is temporarily diverted to the east by a large mass of harder lateritic rock, round which it flows forming a bow, and afterwards turning again to the west. As it approaches the lower coastal plain country the valley assumes a more mature aspect and the stream meanders through a broad swampy course to the south-east of Gingin townsite.

The tributaries of the Brook and other small streams of the area are frequently fed by springs rising at the contacts of strata on the hillsides. Generally they form shallow immature valleys, but in some places very deep miniature canyons have been cut through layers of soft friable rock material. This frequently occurs in soft glauconitic sandstone and also in the chalky limestone. In the former, deep cuts about six feet wide at the top and about 20 feet deep have been formed in several places. On the higher slopes between Poison Hill and Ginginup Hill a number of streams rise and flow to the west across the lower country to the coastal plain. The Moonda and Wowra Brooks, which join the Gingin Brook at the extremity of its bow, rise in the higher country to the east, and as they approach the main stream, widen out into a broad fertile alluvial flat which is covered with a thick sward of couch grass (*Cynodon dactylon*) and rushes.

The highlands of the area are all residuals of erosion of the former plateau. The most extensive is that north of Ginginup Hill, including Poison Hill which is over 800 feet above sea level. The western escarpment of this area of highland is well marked and is generally very steep, but below it lies a very gently sloping area which extends for some distance before it reaches the coastal plain country. To the east the plateau slopes steadily down into the valley of the Gingin Brook. One Tree Hill must be considered as an outlier of this same area of highland. The other highlands are those east of the Brook and the Molecap-Moorgup ridge to the south. These are separated by the Moonda-Wowra valley. The area within the bow of the Gingin Brook is of a different nature. It is a mass of harder material which persists as a hill on account of its greater resistance to erosion than the surrounding rock series.

In the south-western part of the area, the coastal plain country meets the Gingin formation and presents little of physiographic interest.

(b)—*Geology.*

Except for the south-western corner of the area under review, where the deep Muchea sand (see page 92) occurs overlying rocks of more recent origin, the outcropping rocks at Gingin consist of Cretaceous sediments. These sediments which were first recorded by F. T. Gregory (1861) occur or extend in a continuous band some 15 miles wide in a north-westerly direction, from a few miles south of Gingin through Yatheroo and Dandarragan to Jurien Bay, for a distance of over 100 miles. The same series is believed to extend beneath the more recent sediments of the Swan Coastal Plain many miles to the south, and have been encountered in deep borings in the neighbourhood of Perth (Gibb-Maitland, 1919, page 44). The Gingin sediments have been assigned to the lower part of the upper Cretaceous. The highly fossiliferous chalk contains certain characteristic crinoids and ammonites by which the series has been correlated with the lower Santonian (middle Senonian) of the English and European Cretaceous (Gibb-Maitland, 1919, page 46). Further discussion of the geology of the area has recently been published by Forman (1930).

The sediments at Gingin, consisting of upper and lower ferruginous sandstones with an intervening chalk horizon and basal sandstones and shales, are exposed over an area from the west of Poison Hill in the north to a little south of Moorgup Hill. They occupy the valley of the Gingin Brook, and to the east they disappear about three miles from the township. The granite and gneiss of the Darling Plateau lie about eight miles east of Gingin, and the intermediate country consists of a sandy plateau.

The junction of the Gingin sediments with those of the coastal plain is marked by the boundary of the Muchea sand and other soils of the coastal type which bear in a north-westerly direction above Gingin. The coastal plain generally is superficially composed of recent sands and swampy soils with Tertiary limestone patches, and extends to within eight or 10 miles of the coast, where it gives place to the coastal hills of limestone and calcareous wind blown sands.

The uppermost member of the Cretaceous series is a dense ferruginous sandstone or ironstone with a lateritic covering, which, having withstood the agencies of weathering and disintegration, is exposed above a level of 600 to 650 feet. It forms the surface of the table land in the central northern portion of the area, and presents a bold face to the west along the Poison Hill scarp. Further extensions occur to the east above Whakea homestead, and on the south-east in the form of a ridge running in a direction slightly north of east from Moorgup Hill. The soil associated with this series is a deep red sand which has been described as the Whakea sand (see page 82).

These sandstones pass downward into the upper greensands consisting of glauconitic clays, shales and sandstones which vary in colour from cream to very deep green. The colour is due to an abundance of the minerals Glauconite, a hydrated silicate of iron and potassium, and to a lesser degree to Dufrenite, a green phosphate of iron. Exposures of these beds are seen on the steep slopes to the south of Poison Hill and Moorgup where landslides have uncovered them, and in two very deep gullies in the upper part of the Gingin Brook Valley.

The surface exposure of the greensands is marked by a covering of deep red to brown very sandy soils which at the surface appear to be continuous with the Whakea sand. They are, however, characterised by a clay subsoil.

The next and most important member of the series is the Gingin Chalk which forms a very useful stratigraphic horizon. Its occurrence is always indicated by the rich black rendzina soil studded with limestone fragments and formed by weathering and disintegration, in situ, of the chalk and accumulation of organic matter. This soil has been designated the Gingin Clay (see page 80), and the areas of it on the soil map show the extent of the chalk exposures.

It was expected that the chalk would be found in a continuous band, outcropping along the length of the escarpment and slopes of the tableland from Poison Hill to Moorgup. This, however, is not the case. When the beds outcrop on a hillside, debris from the overlying greensands and ferruginous sandstones tend to obliterate the upper boundary of the chalk. Landslides have been quite frequent on the steeper slopes of the plateau, and where they have occurred the surface indications of the chalk are frequently obliterated.

Some distance south of Poison Hill, a recent and somewhat extensive landslide has exposed a wall of greensand and in a creek below, under 20 feet or more of a mixture of red soil, glauconitic clay and sandstone, a black clay profile two feet deep overlying chalk can be seen. Below Moorgup Hill, on the southern side, there is evidence of a chalk outcrop, but another landslide has obliterated the outcrop completely. Even bearing this effect in mind, a study of the contour and soils of the slopes makes it apparent that the chalk is by no means continuous at the surface.

The largest exposure of the Gingin Chalk occurs in a fairly wide band along the intermediate levels of the western escarpment. Its greatest width is over half a mile, but it tails out at Poison Hill in the north and to the south, ends in a tongue-shaped exposure about a quarter of a mile wide south-west of Ginginup Hill. It occurs again on the Ginginup escarpment, at Mt. Pleasant, and as small patches on the hillsides in the eastern portion of the area. Outliers occur at One Tree Hill, Molecap Hill, and on Cheriton to the east of the Gingin Brook.

From the contour data obtained during the course of the survey the thickness of the chalk horizon appears to vary over the area. It is about 25 feet at Poison Hill and 50 feet or more to the south of this. On the top of One Tree Hill there is about 15 feet of chalky limestone overlying greenish glauconite clay. At Molecap the limestone cap is about 12 feet thick, and passes down into a layer of phosphatic nodules about 6-12 feet thick.

Below the chalky limestone with its associated glauconitic sandstones or phosphatic beds, where these occur, is a second horizon of ferruginous sandstones and grits very similar in all respects to that above the chalk. The actual rock material of the lower ferruginous sandstones is rarely exposed, being covered with a deep red sandy soil. It was impossible to delineate the boundary between the upper and lower ferruginous sandstones where the chalk is absent, as the soils formed from each appear to be practically identical.

The central southern portion of the area, covered by the Cheriton gravelly sand (see page 88), is underlain by a dense and massive lateritic formation, which in many places outcrops at the surface.

The main soil types show a good correlation with the stratigraphic horizons, and each geological formation is always associated with its characteristic soil at the surface. The minor soil types have been formed principally by the action of water which has been responsible, in many cases, for leaching of the major soil types, and for the occurrence of swampy and alluvial patches.

Gingin and Dandarragan are two of the few districts in Australia which are abundantly supplied by nature with potash and phosphates, both in the rocks themselves and in certain of the soils. The following minerals are responsible for the unusually high content of potash and phosphate in the soils at Gingin, and their influence is shown by the analyses given later in this paper.

Glauconite (hydrated silicate of iron and potash).
Apatite $Ca_5F(PO_4)_3$.
Dufrenite, $Fe'''_2(OH)_3PO_4$.
Calcite, $CaCO_3$.

A comprehensive account of the mineralogy of the district is given by Simpson (1933).

III.—DESCRIPTION AND CLASSIFICATION OF THE SOILS.

A study of the soil profiles of the area has led to the recognition of 11 distinct types in the field. In addition to these there is a group of poorly drained soils generally swampy in character, which owing to their restricted occurrence and heterogeneous nature do not justify differentiation at the present juncture. Five types are characteristically associated with definite geological strata from which they have been formed in situ while two other equally important types have been produced from one of these as a result of leaching. In general the characteristic profiles of the more extensively developed types are deep.

The broad characteristics of these soil types are summarised in Table 2.

Table 2.

SUMMARY OF SOIL TYPES.

Soil Type.	Area.		Profile.	Topography.	Remarks.
	Acres.	%			
Gingin clay ...	570	3·6	Black sandy clay to heavy clay of very variable depth, over black sandy clay to heavy clay containing calcium carbonate and chalk fragments throughout the profile, on chalky limestone. Profile rich in organic matter.	Upper slopes of the escarpment and summits of chalk outliers	Soil of very variable depth. Deep profiles associated with extensive chalk outcrops along the escarpment, and shallow soils with the outliers. Chalk fragments increase in size and abundance with depth.
Whakea sand	6,318	40·1	Deep profile : grey red to grey-red brown coarse sand with little organic matter 0–15in., over red to red-brown coarse sand 15in.–84in.: fine gravel and occasionally stone throughout the profile.	Plateau, and plateau slopes	Soil associated with ferruginous sandstones and grits. Soil cover varies with the depth of the outcropping rock from more than 20ft. to a mere surface cover. Stone, where present, increases with depth.
Koorian sand	1,641	10·4	Grey to grey-yellow or orange coarse sand with very little organic matter 0–12in., over a yellow to orange coarse sand 12in.–84in.	Plateau slopes	Produced from Whakea Sand by a process of mild leaching.
Wowra sand ..	1,018	6·4	Grey to grey-brown very coarse sand, almost devoid of organic matter, 0–18in., over white very coarse sand 18in.–84in.	Plateau slopes and valleys of tributary creeks.	End product in leaching of sand of the Whakea type.

TABLE 2—*continued.*

SUMMARY OF SOIL TYPES—*continued.*

Soil Type.	Area.		Profile.	Topography.	Remarks.
	Acres.	%			
Moorgup gravelly sand	90	0·6	Dark grey to black fine gravelly coarse sand with very little organic matter 0–15in., over dark grey fine gravelly coarse sand 15in.–30in., over an increasingly yellow or red more gravelly coarse sand.	Summit of plateau outilers	Soil associated with ferruginous sandstones and grits. Occasionally the deeper layers resemble more a fine gravelly deposit than a true soil.
Cheriton gravelly sand	1,535	9·7	Deep profile. Grey, gritty, coarse sand with a little organic matter 0–6in., over cream to yellow coarse sand containing pebbles 6–40in., over coarse sand, becoming lighter in colour, but richer in pebbles, over, massive " lateritic " deposit.	Moderately flat or slightly rolling	Soil cover varies from a deep sand, to a mere surface cover where the " lateritic " or sandstone beds outcrop at the surface.
Minjil sand ...	753	4·8	Grey-yellow to grey-brown, coarse sand with organic matter 0–12in., over yellow to brown sand 12in.–36in., with heavy gravel layer 27in.–36in., over yellow to brown, red mottled, sandy clay 36in.–84in. Gravel decreasing with depth.	Moderately flat or slightly rolling.	Although the gravel is concentrated in a definite band, it occurs both above and below this level.
Mt. Pleasant sand	201	1·3	Grey-red to brown, coarse sand with little organic 0–9in., over red to brown sand 9in.–18in., over a variable depth of vari-coloured and mottled heavy clay. $CaCO_3$ present in deeper clay layers.	Slopes of plateau or outliers immediately below the chalk	Associated with the lower boundary of the Gingin clay and Whakea sand normal phase.
Ballingah sandy loam	152	1·0	Black to grey-brown, coarse (occasionally gravelly) sand, with a little organic matter 0–12in., over grey to red-brown coarse sandy loam 12in.-48in., over vari-coloured sandy clay loam to sandy clay, over decomposing glauconitic rock. Distinct green shade throughout the profile.	Plateau slopes.	Soil associated with glauconitic clay, shale or sandstone outcrop.
Unnamed sand	25	0·2	Grey-brown sand 0–12in., over a brown mottled sandy clay 12in.–20in., over greyish-brown, green, mottled clay 20in.–42in.	Flat.	Along the upper boundary of the type, stone is encountered throughout the profile.
Muchea sand	1,736	11·0	Dark grey to grey coarse sand practically devoid of organic matter 0–12in., over a pure white coarse sand 12in.–60in., over white sand streaked with iron staining. Water table at about 72in.	Flat coastal plain.	At Gingin, owing to the higher level of the country, the water table never encountered ; white sand persists to 84in.
Undifferentiated alluvial and other poorly-drained soils	1,725	10·9	Profile at the fertile Moonda-Wowra Brook flat. Grey organic loam 0–4in., over grey to grey-white sand 4in.–27in., over deep white coarse sand 24in.	Bottomland.	Soils associated with the alluvial flats of the various watercourses and poorly drained areas.

(1)—*Gingin Clay.*

The distinctive heavy black *rendzina* soil associated with the chalk, from which it has been formed *in situ,* has been called the Gingin clay, owing to its characteristic confinement to the chalk horizon of the Gingin Cretaceous series and its heavy texture.

The Gingin clay varies in depth from a few inches to several feet, the shallow profiles from 6 to 18 inches being more generally associated with the chalk outliers and the deep ones with the more extensive outcrops along the escarpment. In the winter the soil is usually somewhat sticky but during the summer, it contracts and extensive fissuring occurs, giving to the soil a distinctly columnar structure. In the deeper soils, cracks about three inches wide and several feet deep are common. The surface has a granular structure when dry and breaks up into fragments of pea size or smaller.

Chalk fragments, varying in size from the finest disintegrated rubble to large unaltered boulders, occur not only throughout the profile but also scattered over the surface of the ground. In the deeper profiles, lime is almost, if not entirely, absent from the surface layers but makes its appearance further down, and the fragments then increase in size and abundance with depth till they merge imperceptibly into the dense unaltered limestone. In the shallow phases where the chalk is never more than 18 inches below the surface, the profile is rich in calcium carbonate throughout. At One Tree Hill the soil varies from 12 to 18 inches in depth, and except for an increasing amount of limestone rubble from the surface downward, there is little differentiation in the profile. The calcium carbonate content is high throughout, amounting to 27 per cent. in the sample taken from this locality. On Molecap Hill the unaltered chalk occurs at a depth of 15 inches and the soil is extremely rich in calcium carbonate, one profile containing 46 per cent. in the first six inches and over 60 per cent. below Shallow profiles also occur along the escarpment where the calcium carbonate is rarely present in the surface layer to the extent of more than about 2 per cent., although it rises to over 30 per cent. below 8 inches. In the field, the Gingin Clay is generally quite black in colour, but occasionally it has a greyish appearance due to admixture with white chalk fragments. In preparing the samples for analysis many of the soft chalk fragments are unavoidably crushed and pass through the 2 mm. sieve causing an unduly high $CaCO_3$ content in the fine earth.

At the surface the Gingin Clay varies in texture from a sandy clay loam at One Tree Hill to a heavy clay in the vicinity of Cleveland. Below the surface horizon the clay content increases only slightly in the shallow phases, but in the deeper profiles heavy clays generally occur in the subsoil. The proportion of silt is low, rarely rising above 5 per cent., whereas the sand is generally somewhat high considering the nature of the soil. Coarse sand predominates in the profiles associated with the escarpment and fine sand in those on the outliers. This soil type is characterised also by the high proportion of organic matter, varying from 4 to over 13 per cent. in the surface with smaller amounts in the subsoil.

The Gingin Clay, owing to its topographical situation, is particularly well drained. In the virgin state, excepting for occasional tea-tree (*Melaleuca Huegelii*) and mannagum (*Acacia microbotrya*) it was practically treeless and carried a rich natural pasture consisting principally of Yatheroo Oat (*Avena barbata*).

The mechanical analyses and chemical data are given in Table 3.

Table 3.—MECHANICAL ANALYSES AND CHEMICAL DATA OF GINGIN CLAY AND MT. PLEASANT SAND.

Soil type	Gingin Clay.								Mt. Pleasant Sand.		
Variation	Shallow.						Deep.				
Sample number	2996	2997	3001	3003	3004	3006	2999	3000	3545	3546–8	3549
Depth in inches	0–8	8–15	0–12	0–6	6–15	0–6	0–12	12–24	0–9	9·52	52–60
Horizon	A	BC	AB	AB	BC	A	A	B	A	B	BC
	%	%	%	%	%	%	%	%	%	%	%
Chalk	...	28	31	14	25	1	...	...	...	...	12*
Fine gravel, 3 mm.—2 mm. ...	...	...	...	...	...	...	1	1	1	1	10
Coarse sand, 2·0 mm.—1·0 mm.	1·9	1·8	0·3	0·3	...	1·7	2·1	1·5	3·5	1·3	0·3
1·0 mm.—0·5 mm.	12·9	9·8	3·2	1·7	1·1	4·2	4·6	3·8	18·1	7·4	1·2
0·5 mm.—0·2 mm.	16·8	11·1	12·5	4·4	2·9	7·6	17·1	13·8	20·3	8·2	2·7
Total ...	31·6	22·7	16·0	6·4	4·0	13·5	23·8	19·1	41·9	16·9	4·2
Fine sand	16·5	12·1	25·1	13·3	9·7	15·9	25·0	21·3	38·1	15·2	21·1
Silt	5·6	2·8	2·6	4·0	2·6	7·4	5·4	3·3	4·9	4·6	10·7
Clay	24·4	18·6	15·8	17·3	12·9	43·8	32·0	43·8	11·7	55·6	48·1
Loss on acid treatment	5·0	35·0	31·5	51·8	66·0	10·7	4·4	5·1	0·6	1·4	12·0
Moisture	6·3	4·7	4·2	4·8	3·7	7·1	5·8	7·1	1·9	8·7	6·0
Calcium Carbonate $CaCO_3$	0·5	30·8	27·1	46·7	62·2	2·6	0·1	0·3	...	...	11·3
Phosphoric acid ... P_2O_5	0·38	0·40	0·21	0·57	0·47	2·24	1·49	1·51	0·06	0·08	0·06
Potash ... ... K_2O	0·78	0·62	0·34	0·45	0·36	1·84	3·15	3·29	0·57	1·83	0·69
Manganese Oxide ... Mn_3O_4	0·014	0·013	0·019	0·021	0·005	0·020	0·007	0·009	...	...	...
Nitrogen ... ... N	0·59	0·29	0·40	0·40	0·26	0·35	0·17	0·10	0·086	0·045	0·021
Organic Carbon ... C ...	7·79	4·46	4·63	5·21	3·54	4·26	2·43	1·28	...	...	...
Organic matter	13·4	7·7	8·0	9·0	6·1	7·3	4·2	2·2	...	...	...
Carbon/nitrogen ratio ... C/N	13·1	15·3	11·5	13·0	13·6	12·2	14·5	13·4	...	...	...
Soil reaction ... ... pH	6·7	7·7	7·9	7·9	8·1	7·7	6·3	7·3	5·5	7·1	8·5

* Stone.

(2)—*Whakea Sand.*

The Whakea sand which covers approximately 40 per cent. of the area surveyed is associated with both the upper and lower ferruginous sandstones and grits from which it is formed *in situ*. It occurs at all levels from the top of the plateau to the rolling downs country. It varies in depth from a mere surface cover on the plateau, where it is associated with outcropping rocks, to a very deep sandy soil estimated at over 20 feet in some places. Fine siliceous gravel is characteristic of the soil as a whole, but whereas the deeper profiles are quite free from stone to a depth of several feet in the shallower varieties ferruginous pebbles are common and increase in size and abundance with depth, gradually merging into the undecomposed rock below.

The soil varies in colour from a bright red to a red-brown or brown. In the virgin state, the surface, to a depth of from 9 to 15 inches, is tinged grey with the small amount of organic matter that is present, but in those areas where the soil has been under cultivation for many years, particularly under lupins, it has a distinct dark chocolate to almost black colour. It was impossible on the scale employed to separate the soils formed from the upper or lower sandstones, although the browner shade was noticed as more characteristic of the soils formed from the latter strata.

The texture of the soil is that of a definitely coarse sand, generally altering only lightly with depth, and although borings were made to over 7 feet, only in a few instances was a sandy clay loam subsoil reached. The high sand content is very characteristic and the ratio of coarse to fine sand averages about 6:1, though frequently it is much wider.

The total sand content of the profile varies between 84 and 96 per cent., with the fine sand tending to increase with depth. In the one subsoil showing clay accumulation the proportion of sand is still above 60 per cent. The silt fraction is remarkably constant at about 4 per cent., and the clay content rarely exceeds about 10 per cent. even in the deeper sand layers. Mechanical analyses and chemical data relating to this soil are given in Tables 4 and 5.

A heavier textured phase of this type is associated with certain outcrops of ferruginous grits on slopes immediately below the plateau level. These patches are recognised as of high productivity particularly of oats and Gingin clovers (*Trifolium cernuum* and *T. glomerata*), and are known locally as Warine soils owing to the natural occurrence of a native Yam (*Dioscorea hastifolia*) of that name which was used by the natives as a food.

Owing to the elevation and very sandy nature of the Whakea sand, the drainage is particularly good, especially on the steeper slopes. This soil has been cleared almost entirely, the only timber remaining being scattered marri (*Eucalyptus calophylla*). Isolated patches of regrowth, however, show parrot bush (*Dryandra floribunda*), various banksias including *Banksia Menziesii,* and *B. attenuata* and a blackboy (*Xanthorrhoea gracillis*).

Table 4.—MECHANICAL ANALYSES AND CHEMICAL DATA OF WHAKEA SAND.

Soil Type.	Whakea Sand.											
Sample Number	3025	3026	3027	3010	3011	3012	3007	3008	3009	3022	3023	3024
Depth in inches	0–15	15–60	60–80	0–15	15–60	60–80	0–15	15–60	60–80	0–15	15–60	60–80
Horizon	A_1	A_2		A_1	A_2		A_1	A_2		A_1	A_2	
	%	%	%	%	%	%	%	%	%	%	%	%
Stone	...	...	...	...	...	...	...	...	...	...	...	...
Fine gravel, 3 mm.—2 mm. ...	2	3	6	...	1	2	1	1	1	1	1	3
Coarse sand 2·0 mm.—1·0 mm.	23·1	24·3	19·5	25·2	20·0	17·6	9·7	9·2	10·3	8·5	9·0	9·7
1·0 mm.—0·5 mm.	47·1	38·3	32·6	54·9	48·9	45·4	27·1	27·1	19·5	12·2	17·9	14·2
0·5 mm.—0·2 mm.	17·9	23·2	25·6	4·8	9·9	12·2	29·1	28·1	32·0	40·6	29·7	27·2
Total	88·1	85·8	77·7	84·9	78·8	75·2	65·9	64·4	61·8	61·3	56·6	51·1
Fine sand	7·5	10·7	17·5	6·5	10·1	12·4	18·3	19·7	22·8	24·6	29·3	34·8
Silt	1·6	1·5	2·7	3·1	4·3	3·8	4·7	5·2	4·8	5·2	5·8	5·0
Clay	1·7	1·8	2·0	4·3	6·2	8·4	8·7	9·7	9·9	8·0	8·2	9·0
Loss on acid treatment ...	0·3	0·1	0·2	0·3	0·2	0·3	0·2	0·1	0·1	0·2	0·2	0·2
Moisture	0·2	0·2	0·2	0·4	0·4	0·5	0·9	0·9	0·8	0·6	0·6	0·6
Phosphoric acid ... ... P_2O_5	0·049	0·051	0·051	0·042	0·041	0·041	0·061	0·050	0·041	0·025	0·023	0·022
Potash ... ... K_2O	0·031	0·037	0·045	0·025	0·036	0·039	0·054	0·044	0·039	0·027	0·028	0·033
Manganese Oxide ... Mn_3O_4	...	...	...	0·001	0·002	0·001	0·001	0·001	0·002	...	...	...
Nitrogen ... ... N	0·035	0·009	0·006	0·027	0·011	0·009	0·078	0·023	0·013	0·019	0·010	0·009
Organic carbon C	0·63	...	...	0·55	...	...	1·28	0·49	0·210	...	...	...
Carbon/nitrogen ratio ... C/N	18·0	...	...	20·2	...	...	16·4	21·3	16·1	...	...	...
Soil reaction ... ... pH	6·0	6·1	6·3	6·4	6·4	6·5	6·4	6·5	6·5	6·3	6·3	6·3

Table 5.—Mechanical Analyses and Chemical Data of the Whakea Sand and Koorian Sand.

Soil type	Whakea Sand.							Koorian Sand.					
Variation	Normal.							Yellow coloured.				Orange coloured.	
Sample Number	3013	3014	3015	3017	3018	3019	3020	3032	3033–4	3037	3038	3035	3036
Depth in inches	0–15	15–54	54–66	0–12	12–42	42–60	60–80	0–12	12–80	0–6	6–42	0–12	12–80
Horizon	A_1	A_2		A_1	A_2	B		A_1	A_2	A_1	A_2	A_1	A_2
	%	%	%	%	%	%	%	%	%	%	%	%	%
Stone	...	...	2	...	...	2	7	...	...	...	...	...	...
Fine gravel 3 mm.—2 mm. ...	3	6	16	3	3	8	6	...	...	...	...	...	...
Coarse sand,													
2·0 mm.—1·0 mm.	13·8	12·7	14·7	10·1	10·0	7·9	10·3	16·4	20·6	2·6	3·2	2·7	2·6
1·0 mm.—0·5 mm.	24·7	15·6	14·6	22·3	22·5	15·9	15·5	59·1	55·6	39·3	29·0	10·6	8·9
0·5 mm.—0·2 mm.	22·7	24·2	19·3	26·1	26·3	22·6	18·3	7·5	10·3	39·8	41·9	51·5	46·9
Total	61·2	52·5	48·6	58·6	58·8	46·4	44·1	83·0	86·5	81·7	74·1	64·8	58·4
Fine sand	23·0	30·4	33·2	22·4	20·5	21·7	19·6	8·2	5·8	12·5	18·8	26·2	32·8
Silt	3·5	3·8	5·0	4·4	3·0	3·3	6·2	3·4	1·5	1·2	1·3	1·8	1·6
Clay	9·1	11·8	12·4	12·1	16·0	26·2	27·0	4·1	6·0	3·6	5·2	5·0	6·4
Loss on acid treatment ...	0·5	0·2	0·1	0·2	0·1	0·0	0·2	0·4	0·1	0·2	0·1	0·3	0·2
Moisture	0·9	0·8	0·8	1·2	1·1	2·5	3·6	0·4	0·2	0·2	0·3	0·5	0·4
Phosphoric acid P_2O_5	0·085	0·068	0·059	0·069	0·067	0·067	0·107	0·010	0·009	0·004	0·002	0·019	0·016
Potash ... ... K_2O	0·059	0·069	0·065	0·154	0·160	0·237	0·313	0·020	0·027	0·022	0·025	0·034	0·031
Manganese oxide Mn_3O_4	0·002	0·001	0·003	0·003	...	...	...	...	...	...	...	...	...
Nitrogen ... N	0·070	0·026	0·019	0·055	0·029	0·029	0·024	0·044	0·009	0·019	0·010	0·038	0·011
Organic carbon C	1·31	0·49	0·44	0·98	...	...	...	1·04	0·20	0·47	...	0·81	...
Carbon/nitrogen ratio C/N	18·8	18·8	23·1	17·9	...	...	...	23·6	22·1	24·7	...	21·2	...
Soil reaction ... pH	6·2	6·3	6·4	5·9	6·0	5·9	6·0	5·9	6·2	5·9	6·2	6·1	6·5

(3)—*Koorian Sand.*

The Koorian sand is distributed throughout the district in moderately extensive patches and occupies about 10 per cent. of the total area. It appears to have been formed from the Whakea sand by a process of moderate leaching, but on the other hand, where it is found on the lower levels of the downs country, it may have originated from the less ferruginous lower members of the Cretaceous system. The boundary between the normal Whakea sand and this type is often quite indefinite, the change from the one to the other being gradual and indicated by an orange-coloured transitional soil. To the west of One Tree Hill and again in the north-west corner of the area, this orange-coloured variation of the Koorian sand occupies a large area, but has been included with this type, with which it shows more affinity. At the other extreme the Koorian sand merges into a phase of the highly leached Wowra sand.

The profile varies in colour from brownish yellow to yellow or orange, the surface layers having a somewhat greyer shade in the virgin state, due to organic matter. Where lupins have been cultivated on this soil the surface, like the Whakea sand, may be almost black in colour. In texture the profile is remarkably uniform throughout, and resembles the Whakea sand both in the coarseness of the sand and in the occasional occurrence of stone on the surface and throughout the profile. Fine gravel, however, is absent.

The total sand content amounts to over 90 per cent. in every case examined, but whereas in the yellow variety the coarse sand is always very high, in the orange variety examined it is some 20 per cent. lower. The clay content is generally somewhat lower than in the Whakea sand. Although the soil was sampled to over 84 inches, a heavy subsoil was never encountered. Mechanical analyses and chemical data relating to the type are given in Table 5.

In these well drained soils, marri (*E. calophylla*) are again dominant, excepting in the vicinity of the Wowra and Muchea sands, when the banksias (*B. prionotes* and *B. attenuata*) become more prominent. In the virgin state parrot bush (*Dryandra floribunda*), furze stinkwood (*Jacksonia furcellata*), other banksias (*B. Menziesii* and *B. grandis*), blackboys (*X. gracillis, X. spp.*), zamia palm (*Macrozamia Reidlei*), and blue billy (*Stirlingia latifolia*) are common.

(4)—*Wowra Sand.*

In the south-eastern corner of the area at a level of 400 to 600 feet, there is developed a very deep white coarse sand which has no doubt been formed by the extensive leaching of the sands of the Whakea type. Further occurrences much more restricted in extent are found throughout the district along the courses of short tributary creeks. Many of these areas are of only recent origin, being associated with springs which have developed since clearing, and are slowly extending into the surrounding Whakea or Koorian sands. In the neighbourhood of these springs on the alluvial flats, where poorer drainage conditions exist, the Wowra sand passes gradually into swampy soils.

The normal profile, which is extremely uniform in texture throughout, consists of a light grey or grey-brown to almost white, very coarse loose sand, from 12-18 in. deep, and practically devoid of organic matter, over pure white to pinkish very coarse sand to a depth of more than 7 feet. The coarse sand alone amounts to more than 90 per cent., of which over 80 per cent. has a grain size greater than 0.5 mm. As would be expected from the intense leaching these soils have undergone, not only the silt and clay fractions but also all plant nutrients are virtually absent.

This sand is of little value either agriculturally or pastorally. Analyses of two profiles are given in Table 6.

The vegetation consists of several banksias (*B. prionotes*) characteristic of deep sands, (*B. attenuata, B. grandis*), blackboys (*Xanthorrhoea gracilis, X. Preissii, X. reflexa*), Christmas bush (*Nuytsia floribunda*), zamia palm (*Macrozamia Reidlii*), parrot bush (*Dryandra floribunda*), furze stinkwood (*Jacksonia furcellata*), hakea (*Hakea prostrata*), with an occasional coastal blackbutt (*Eucalyptus Todtiana*) and marri (*E. calophylla*), with a ground cover of blue billy (*Stirlingia latifolia*), scrub tea-tree (*Melaleuca trichophylla*), *Calythrix angulata*, *Scholtzia umbellifera*, and various heaths. Grasses are almost, if not entirely, absent.

Where moister conditions prevail, tea-trees (*Melaleuca spp.*), black wattle (*Acacia cyanophylla*), together with bracken fern (*Pteridium aquilinum*), are more common.

Table 6.—MECHANICAL ANALYSES AND CHEMICAL DATA OF THE WOWRA SAND, MOORGUP GRAVELLY SAND AND CHERITON GRAVELLY SAND.

Soil type	Wowra Sand.				Moorgup Gravelly Sand.		Cheriton Gravelly Sand.					
Variation	—				—		Deep profile.					
Sample Number	3052	3053	3054	3055	3029	3030	3065	3066	3067	3069	3070–1	3072
Depth in inches	0–18	18–45	0–18	18–45	0–15	15–45	0–4	4–18	18–24	0–6	6–42	42–48
Horizon	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_2	A_1	A_2	A_2
	%	%	%	%	%	%	%	%	%	%	%	%
Stone	...	...	...	...	...	...	...	...	25	...	3	23
Fine gravel 3 mm.—2 mm.	...	...	...	...	5	7	...	3	3	2	2	4
Coarse sand 2·0 mm.—1·0 mm.	15·7	15·3	41·1	23·4	19·7	22·2	4·7	5·1	4·0	5·2	7·4	10·6
1·0 mm.—0·5 mm.	63·4	53·8	55·1	65·7	35·6	31·7	20·9	19·0	15·9	20·1	15·6	16·3
0·5 mm.—0·2 mm.	15·9	21·3	1·6	7·0	26·5	28·5	46·3	46·9	44·2	43·1	39·6	37·9
Total	95·0	90·4	97·8	96·1	81·8	82·4	71·9	71·0	64·1	69·4	62·6	64·8
Fine sand	3·7	8·5	1·3	3·2	10·1	11·9	22·8	24·7	31·0	25·0	33·4	32·0
Silt	} 0·3	0·7	0·3	0·6 {	2·1	1·7	1·3	1·5	1·6	1·4	1·4	1·4
Clay					2·9	2·9	1·7	2·1	2·8	2·2	2·0	1·4
Loss on acid treatment	0·0	0·0	0·0	0·0	0·5	0·3	0·3	0·1	0·1	0·3	0·1	0·1
Moisture	0·2	0·0	0·1	0·0	0·7	0·3	0·4	0·2	0·2	0·3	0·2	0·1
Phosphoric acid ... P_2O_5	Tr.	Tr.	0·002	Tr.	0·036	0·035	0·010	0·003	0·002	0·010	0·004	0·002
Potash ... K_2O	0·011	0·005	0·006	0·007	0·018	0·018	0·018	0·012	0·015	0·015	0·012	0·006
Nitrogen ... N	0·041	0·005	0·015	0·001	0·078	0·023	0·059	0·012	0·009	0·044	0·010	0·006
Organic carbon ... C	0·71	0·076	0·35	...	1·66	0·57	0·991	0·217	0·160	0·753	0·127	...
Carbon/nitrogen ratio ... C/N	17·2	15·2	18·3	...	21·3	24·9	16·8	18·1	15·6	17·1	12·7	...
Soil reaction ... pH	5·3	6·2	6·1	6·0	6·4	6·8	6·2	6·1	6·3	6·2	6·2	6·3

(5)—*Moorgup Gravelly Sand.*

Associated with the Whakea sand, there occurs, on the summits of the plateau outliers above the Whakea homestead and along the Moorgup ridge, a deep dry and loose coarse sand, rich in fine gravel, which has been named the Moorgup gravelly sand. The surface, although containing little organic matter, varies in colour from a dark grey to almost black. At about 12 to 15 inches the colour becomes lighter, and at 30 inches changes to a grey yellow or grey red, which colours become more marked with depth. Over 5 per cent. of fine gravel was found throughout the profile sampled and the sand content, principally coarse sand, constituted over 90 per cent. Below about 30 inches the soil often changes to a fine gravelly horizon. The mechanical analysis and chemical data of a profile of this type are given in Table 6.

The areas have been cleared but a few marri (*B. calophylla*) remain and banksias (*B. prionotes* and *B. grandis*) are common.

These soils, like the Wowra sand, are regarded as of low fertility for either farming or grazing purposes.

(6)—*Cheriton Gravelly Sand.*

The Cheriton gravelly sand occupies a moderately extensive and almost continuous belt, broken only by the alluvium of the Gingin Brook, in the central southern portion of the area, including the townsite. It consists of a very gritty sand of variable depth overlying a massive "lateritic" or iron-stone gravel bed, which frequently outcrops at the surface and forms a layer, not penetrable with the ordinary borer or crowbar. The soil varies from a mere surface cover to several feet in depth, and contains throughout the profile pebbles which increase in abundance and merge into the gravel bed below. In the shallow soils the pebbles occur at the surface. Evidence from more complete profiles exposed in several cuttings suggests that the gravel bed rests on a yellow to brown sandy clay. Drainage appears particularly free, the soil generally being very loose and dry.

The deeper profiles show below the normal coarse sandy surface, coloured grey by organic matter, a white, cream to yellow coarse sand containing up to 25 per cent. of "lateritic" pebbles in its lower layers. The yellow colour of the subsurface reaches its maximum intensity at about 36 to 42 inches, thereafter becoming almost white again.

Two of the deeper profiles have been examined in detail. As with the other soils of the district, the proportion of sand is extremely high, amounting to over 90 per cent. throughout the profile examined, the ratio of coarse to fine sand being of the order of 3 : 1 in the surface and 2 : 1 in the subsurface horizon. Fine gravel, present in small amounts, has with the sand a characteristic gritty feel. Silt and clay are negligible.

Mechanical analyses and chemical data of these soils are given in Table 6.

Three vegetation associations were observed on this soil type:—

1. Where the soil is deep the vegetation consists of an almost pure forest of marri (*E. calophylla*).
3. As the soils become shallower, or as they approach the sands of the coastal plain, the marri are gradually replaced by banksias.
3. On the shallowest soils this association in turn becomes less prominent, and the trunkless blackboy (*Xanthorrhoea gracilis*) becomes dominant.

The natural vegetation of the second and third associations consists of various banksias (*B. Menziesii*) typical of gravelly soils (*B. attenuata, B. grandis,* and *B. prionotes*), furze stinkwood (*Jacksonia furcellata*), Christmas bush (*Nuytsia floribunda*), prickly poison (*Gastrolobium spinosum*), blackboys (*X. gracillis, X. Preissii, X. reflexa*), and hakea (*Hakea prostrata*), with blue billy (*Stirlingia latifolia*) in the vicinity of the coastal sands.

(7)—*Minjil Sand.*

Apart from the soils of the bottomlands, this type is found at the lowest levels of the Cretaceous country, and in the yellower variation occasionally shows signs of incipient swampiness, as evidenced by the presence of blue gums, rushes and reeds. The browner variation is slightly more elevated, and appears to be associated with outcrops rich in glauconitic material, as shown by the content of phosphate and potash.

The type is characterised by (a) its yellow to brown colour and weakly podsolised nature, (b) the fine gravel throughout the profile, and (c) a band of lateritic and ferruginous pebbles, varying in thickness from three to 20 inches, usually encountered at about 30 inches. To a depth of 36 inches the soil consists of a yellow to brown coarse sand, the first 12 inches being somewhat greyer in shade due to organic matter. The gravel layer occurs in the lower levels of the sand and overlies a yellow to yellow brown, red mottled, sandy clay which becomes lighter in texture below 60 inches. The gravel does occur over a limited range, both in the sand above the gravelly layer and in the clay below it, but rapidly dies out in either direction. The sand content of the A. horizon amounts to from 84 to 88 per cent., of which three-quarters is coarse sand. The silt amounts to barely three per cent., while the clay varies from five to 10 per cent. In the subsoil the ratio of coarse to fine sand persists, although the total sand fraction is only about 60 per cent., the silt rises slightly and the clay attains an average of about 30 per cent.

Occurring as it does on the lower slopes and having a shallow clayey subsoil, the drainage is somewhat restricted, portions being even swampy in nature. On the more elevated situations, marri (*Eucalyptus calophylla*) and wattles (*Acacia spp.*) are common, whereas the associated vegetation under restricted drainage conditions consists of flooded gums (*E. rudis*), fresh water paper bark (*Melaleuca rhaphiophylla*) and various reeds and rushes.

Mechanical analyses and chemical data for the type are given in Tables 7 and 8.

Table 7.

MECHANICAL ANALYSES AND CHEMICAL DATA OF THE MINJIL SAND.

Soil type	Minjil sand.												
Variation	Yellow surface soil.						Intermediate.				Brown surface soil.		
Sample Number	3039	3040	3041	3043	3044	3045	3560	3561	3562–3	3564–6	3047	3048	3049
Depth in inches	0–15	15–30	30–60	0–6	6–27	27–33	0–12	12–24	24–43	43–72	0–12	12–27	27–33
Horizon	A_1	A_2	B	A_1	A_2		A_1	A_2		B	A_1	A_2	
	%	%	%	%	%	%	%	%	%	%	%	%	%
Stone	...	...	...	...	1	9	1	2	20	2	...	...	7
Fine gravel, 3 mm.—2 mm.	1	2	4	1	1	4	1	1	5	2	1	3	3
Coarse sand,													
2·0 mm.—1·0 mm.	6·8	6·7	8·8	4·3	4·7	9·9	3·8	3·0	8·0	4·8	7·6	9·7	9·8
1·0 mm.—0·5 mm.	18·9	15·6	11·6	23·6	19·6	20·2	24·2	17·6	16·8	15·6	22·0	16·5	18·7
0·5 mm.—0·2 mm.	33·3	34·0	22·6	40·2	36·5	31·1	38·3	37·1	32·2	23·7	33·1	28·2	22·9
Total	59·0	56·3	43·0	68·1	60·8	61·2	66·3	57·7	57·0	44·1	62·7	54·4	51·4
Fine sand	25·3	31·2	24·2	20·6	24·4	23·0	21·0	27·9	26·7	18·3	25·9	31·6	28·8
Silt	3·0	4·1	6·0	2·3	2·1	2·3	3·0	3·1	3·0	4·8	2·7	3·2	3·4
Clay	8·2	7·3	25·9	6·9	11·8	12·6	8·1	10·1	12·6	29·9	5·6	8·5	13·1
Loss on acid treatment ...	0·4	0·1	0·1	0·1	0·0	0·0	0·2	0·2	0·2	0·4	0·0	0·4	0·2
Moisture	1·1	0·6	1·8	0·7	0·7	0·8	0·5	0·6	1·0	4·1	1·3	1·7	2·7
Phosphoric acid ... P_2O_5	0·046	0·028	0·047	0·018	0·022	0·022	0·022	0·026	0·033	0·041	0·187	0·247	0·412
Potash ... ... K_2O	0·050	0·041	0·035	0·041	0·054	0·054	0·035	0·041	0·046	0·651	0·682	0·826	0·967
Nitrogen ... ... N	0·106	0·021	0·020	0·052	0·038	0·018	0·039	0·025	0·020	0·011	0·070	0·039	0·047
Organic carbon ... C	1·80	0·33	...	0·86	...	...	...	...	...	...	1·00	0·46	0·52
Carbon/nitrogen ratio C/N	17·0	15·7	...	16·5	...	...	...	...	...	...	14·3	11·7	11·2
Soil reaction ... ... pH	5·9	6·4	6·5	6·0	6·4	6·7	5·8	6·2	6·4	5·2	5·7	5·6	5·4

Table 8.

MECHANICAL ANALYSES AND CHEMICAL DATA OF THE MINJIL SAND, BALLINGAH SANDY LOAM, AND THE UNNAMED SAND.

Soil type	Minjil Sand.				Ballingah Sandy Loam.			Unnamed Sand.	
Variation	Brown Surface Soil.				——			——	
Sample Number	3551	3552	3553	3554–8	3538	3539–42	3543	3050	3051
Depth in Inches	0–12	12–24	24–28	29–80	0–12	12–60	60–72	0–6	6–45
Horizon	A_1	A_2		B	A	B	BC	A	B
	%	%	%	%	%	%	%	%	%
Stone	1	4	30	2	..	...	...	1	1
Fine gravel 3 mm.—2 mm	2	3	7	4	3	1	...	2	...
Coarse sand :									
2·0 mm.—1·0 mm.	8·7	8·8	12·3	6·9	11·6	2·3	0·4	7·6	3·8
1·0 mm.—0·5 mm. ...	23·4	20·8	19·7	13·9	19·5	5·0	1·3	23·8	13·4
0·5 mm.—0·2 mm. ...	31·6	32·3	30·9	21·5	21·9	34·0	33·5	23·5	14·8
Total ...	63·7	61·9	62·9	42·3	53·0	41·3	35·2	54·9	32·0
Fine sand	22·5	25·7	25·7	19·7	26·9	25·6	23·9	27·6	17·2
Silt	3·1	1·8	2·1	2·8	4·7	6·6	6·7	3·3	4·6
Clay	7·4	8·3	7·9	30·7	10·8	18·6	25·8	10·1	40·4
Loss on acid treatment ...	0·2	0·4	0·3	0·6	0·6	0·8	0·9	0·4	0·9
Moisture	1·3	1·1	1·1	4·7	2·9	7·2	8·8	1·5	5·5
Phosphoric acid P_2O_5	0·092	0·090	0·142	0·084	0·77	1·91	1·59	0·059	0·066
Potash ... K_2O	0·180	0·184	0·199	0·338	1·80	4·12	4·38	0·535	1·706
Nitrogen ... N	0·068	0·033	0·025	0·017	0·067	0·032	0·024	0·093	0·031
Organic carbon C	...	...	...	...	...	...	...	1·151	0·266
Carbon/nitrogen ratio C/N	...	...	...	...	...	...	...	12·4	8·6
Soil reaction ... pH	5·7	6·0	6·4	5·2	5·3	5·4	5·5	5·7	7·1

(8)—*Mount Pleasant Sand.*

This type is very restricted in extent, and is associated with the junction of the chalk and lower greensand. The surface layer, a red to dark chocolate sand almost identical with that of the Whakea sand overlies a variable thickness of red, reddish yellow, brown or grey mottled clay, occurring at a depth of from nine to 24 inches. This clay, often containing calcium carbonate in the deeper layers, overlies the decomposing rock, fragments of which may occur throughout the profile. In the surface the proportion of fine sand is generally higher than in the Whakea sand, and although the clay content rises abruptly to over 50 per cent. in the subsoil, the silt content even in the deepest layers, remains practically constant, at about four per cent. throughout the profile. Data relating to this type are given in Table 3.

Drainage conditions appear somewhat restricted in certain areas, but the type is considered favourably from an agricultural point of view. The Mount Pleasant sand has been completely cleared except for a few marri (*E. calophylla*). The original vegetation most probably resembled that of the Whakea sand.

(9)—*Ballingah Sandy Loam.*

Like the former type the Ballingah sandy loam is very limited in extent, and occurs in isolated patches throughout the Whakea sand areas. The actual boundary between these types in the field is often extremely difficult to trace owing to the great similarity in colour and texture at the surface. The Ballingah type, however has a distinct brownish-green shade and slightly heavier texture which becomes apparent on closer inspection.

This soil occurs *in situ* associated with the outcrops of glauconitic clays and standstone, decomposing fragments of which occur abundantly throughout the profile. The fine sand fraction separated by mechanical analysis is always a dark green in colour, reflecting the high percentage of glauconitic material which is present.

The surface consists of a black to grey-brown coarse, occasionally gravelly, sand to sandy loam with little organic matter, to a depth of about 12 inches, where the soil changes to a distinct sandy loam and finally to a sandy clay loam or light clay, which overlies at varying depth the basal rock. The colour of the clay varies from a red, through greenish brown to a distinct green, with variegated mottling. The total sand content in the surface is about 80 per cent., but falls to less than 60 per cent. in the subsoil, as the clay content increases. Silt amounting to about five per cent. increases only slightly with depth. Data referring to this type will be found in Table 8.

This soil does not suffer from drought as do most of the sandy soils and is recognised as one of the most fertile arable and pasture soils of the district. Like that of the Mount Pleasant sand the original vegetation of the Ballingah sandy loam was most probably similar to that of the Whakea type.

(10)—*Unnamed Sand.*

To the west of Whakea homestead on the eastern bank of the Gingin Brook, there is an area of soil about 25 acres in extent totally unlike any other profile so far described. A grey brown surface sand containing a little organic matter and averaging 6-12 inches in thickness, overlies a brownish green mottled sandy clay which becomes slightly heavier at about 20 inches, changing in colour to a greyish brown or green with reddish yellow mottling. Fine gravel is present in the surface and in the part most remote from the brook, stone is often encountered at shallow depths. The mechanical analysis and chemical data of a profile of this type will be found in Table 8.

The area has been practically cleared, but isolated tea-trees (*Melaleuca* spp.) and flooded gums (*E. rudis*), rushes and reeds are still present.

(11)—*Muchea Sand.*

The south-western portion of the area is covered by a sandy soil overlying the more recent tertiary deposits of the coastal plain. Although practically useless from an agricultural point of view its interest lines in the fact that it represents a climax in the process of podsolisation. This soil type has an extremely wide distribution on the western coastal plain and owing to its typical development at Muchea, a small township 18 miles south of Gingin, has been named the Muchea sand.

The normal profile consists of a deep white coarse sand. Except for decomposing root material the soil is practically devoid of organic matter, and the small amount, which gives a greyish shade to the surface layer, disappears completely at about 18 inches. In typical profiles near Muchea the white sand has a brown streaked appearance due to iron staining, at about five feet and the water table occurs at about six feet. In the vicinity of Gingin, however, the soil occurs at a somewhat higher level, the water table is deeper, and the brown streaked layer was not encountered in the sites sampled. Near the boundary with the other soil types of the area the sand has a yellow shade.

The soil consists almost entirely of siliceous sand, silt and clay being less than one per cent. and plant nutrients virtually absent. The ratio of coarse to fine sand is always wide but decreases from 7 : 1 in the surface to 3 : 1 in the deep sub-surface. Fine gravel characteristic of most of the Cretaceous soils is entirely absent, although the predominating portion of the coarse sand fraction, which amounts to from 50 to 60 per cent. of the soil, is that between 1.0 mm. and 0.25 mm. Mechanical analyses and chemical data of the Muchea sand are given in Table 9.

Swampy and poorly drained patches are frequent throughout the type. The surface of these is somewhat loamy in texture and overlies in extreme cases a sandy clay layer which, however, changes to a white or iron-stained sand of the normal type at about 24 inches. The surface varies in colour from grey to black owing to the increased organic matter accumulation. These soils are included with the poorly drained soils on the map.

Outside the area of the Gingin Soil Survey, sheoak (*Casuarina glauca*) flats are common in this type. The soils of these flats are grey sandy loams over a cemented sandy clay subsoil at a depth of about 8 to 12 inches. No profiles of this type have been examined during this survey.

The species which constitute the vegetation of the Muchea sand are practically identical with those occurring on the Wowra sand, but they occur in several associations which are definitely related to the varying conditions of drainage. The banksia-blackboy association of the Wowra sand is characteristic of the deeper better drained phases, but where the water table is closer to the surface, *Regelia ciliata,* paperbark trees (*M. rhaphiophylla*), tea-trees (*Melaleuca* spp.), swamp spearwood (*Kunzea ericafolia*), and black wattle (*Acacia cyanophylla*) become more common.

Table 9.

MECHANICAL ANALYSES AND CHEMICAL DATA OF THE MUCHEA SAND AND ALLUVIAL AND POORLY DRAINED SOILS.

Soil type	Muchea Sand.						Alluvial and other Poorly Drained Soils.							
Variation	Normal.						Moonda-Wowra Brook Alluvial Flat.			Alluvial.			Undrained Sandy Soil.	
Sample number	3076	3077–8	3074	3075	3079	3080	3061	3062–3	3064	3568	3569	3570	3058	3059–60
Depth in inches	0–12	12–80	0–6	6–80	0–15	15–45	0–4	4–33	33–45	0–12	12–24	24–45	0–9	9–45
Horizon	A_1	A_2	A_1	A_2	A_1	A_2	A_1	A_2	A_2	A_1	A_2	A_2	A_1	A_2
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Stone	...	...	...	...	...	...	...	...	...	...	...	1	...	...
Fine gravel, 3 mm.–2 mm.	...	...	...	...	...	...	...	...	...	2	3	4	...	1
Coarse sand:														
2·0 mm.–1·0 mm. ...	6·2	6·9	3·1	6·8	3·9	7·6	2·9	5·0	6·8	5·4	1·6	12·7	6·6	6·4
1·0 mm.–0·5 mm. ...	45·0	28·2	39·4	28·0	33·2	24·0	9·4	20·7	24·8	19·7	8·3	20·2	27·4	23·8
0·5 mm.–0·2 mm. ...	34·3	41·9	41·2	39·0	47·0	41·3	20·0	47·1	46·5	15·7	10·2	19·3	33·4	33·6
Total	85·5	77·0	83·7	73·8	84·1	72·9	32·3	72·8	78·1	40·8	20·1	52·2	67·4	63·8
Fine sand	11·8	21·7	14·1	24·8	12·4	25·3	16·3	16·0	17·1	16·5	20·8	20·5	27·8	33·0
Silt	0·3	1·0	1·0	1·3	1·0	1·5	19·5	6·7	3·7	25·0	30·7	6·5	1·9	2·8
Clay							16·0	3·5	1·0	12·9	24·5	17·9		
Loss on acid treatment ...	0·0	0·0	0·0	0·0	0·2	0·0	1·2	0·2	0·1	0·7	0·7	0·4	0·1	0·0
Moisture	0·3	0·1	0·2	0·0	0·3	0·0	4·4	0·5	0·2	2·6	3·6	2·5	0·5	0·1
Phosphoric Acid ... P_2O_5	Tr	Tr	0·001	Tr	0·001	0·001	0·068	0·013	0·001	0·016	0·016	0·010	0·013	0·005
Potash ... ... K_2O	0·005	0·004	0·005	0·005	0·007	0·004	0·034	0·008	0·004	0·040	0·026	0·048	0·014	0·010
Nitrogen ... ... N	0·039	0·005	0·026	0·004	0·056	0·005	0·421	0·025	0·006	0·098	0·029	0·023	0·073	0·009
Organic carbon ... C	1·212	0·135	0·544	...	1·041	0·096	5·91	0·356	...	...	...	...	1·10	0·15
Carbon/nitrogen ratio C/N	31·1	27·0	20·9	...	18·6	19·2	14·0	14·2	...	...	...	...	15·1	13·6
Soil reaction ... ... pH	5·3	5·3	5·5	6·2	5·1	5·1	4·9	6·1	6·2	5·8	6·4	6·9	5·6	6·2

(12)—*Undifferentiated Alluvial and other poorly drained Soils.*

Associated with the brook and spring system of the district there is a group of soils, many of which are swampy in the undrained state. This group is by no means homogenous, and the profiles are, to a large extent, governed by the adjacent soil types. Along the courses of the streams, the profile consists generally of about 12 inches of a brown to black organic loam overlying a black organic clay which gradually becomes lighter in colour and texture with depth and eventually passes into a sand. The water table is practically at the surface, and hydrogen sulphide is common throughout the profile. In the vicinity of Gingin, where the brook passes over the lateritic beds, ironstone gravel occurs in these soils and the clay continues to a greater depth.

To the west of Gingin where the brook flows out on to the coastal plain these soils show more affinity with the sands of the Muchea type. The profile consists of a sandy loam surface overlying a grey sand with more or less ironstained sand below.

To the east of the town the Moonda and Wowra Brooks pass through a large fertile alluvial flat before their confluence with the Gingin Brook. The profile of this flat, which is fairly uniform, is as follows:—

Grey organic loam 0-4″.

Grey to white sand 4-30″.

White coarse sand (similar to the Wowra sand subsoil) 30″+.

The silt and clay, which are present in the surface soils in much larger amounts than in the previously described sandy soils, fall away to small figures in the subsurface, whereas the sand content almost doubles itself, and increase in coarseness. A second alluvial profile which appears to occur in isolated areas along the banks of the brooks has a grey colour throughout and is again characterised by an even higher percentage of silt and clay in the surface and subsurface soils. The subsurface is as usual high in sand, especially coarse sand. Chemical data and mechanical analyses of these two profiles are given in Table 9.

On the higher levels, above these bottomlands in proximity to the Wowra sand, deep white sands occur which, owing to swampy conditions, carry a dense growth of rushes and reeds or grasses. While showing many affinities with the Wowra sand, the poorly drained nature of these soils combined with the organic accumulation at the surface make their inclusion in this group a more natural one. An analysis of this type of profile is shown in Table 9. The area to the north-east of Granville, occurring in a distinct depression, is in places submerged below the water-table, and is included with these soils.

Along the actual course of the Gingin Brook and to a lesser extent along the Wowra and Moonda Brooks giant fresh-water paperbarks (*Melaleuca rhaphiophylla*) grow to a height of from 25-40 feet under the most swampy conditions while somewhat smaller tea-trees (*Melaleuca spp.*) also occur together with a ground cover of bracken fern (*Pteridium aquilinum*). Various rushes (*Juncus spp.*), nut grasses (*Cyperus spp*), together with a small amount of couch grass (*Cynodon dactylon*), Guildford grass (*Romulea rosea*), and grasses characterised the cleared flats.

IV.—LABORATORY INVESTIGATIONS.

(1)—*Mechanical Analyses.*

Mechanical analyses were carried out on 104 samples taken from the 34 sites, and representative of all soil types; a selection of typical examples is tabulated in the text.

Apart from the Gingin clay and the surface alluvial samples, the surface and subsurface soils are exceptionally light and coarse in texture, being characterised not only by the high sand content but also by the high proportion of coarse sand present. The total sand content ranges from 83 per cent. in some of the Whakea sand samples to practically 100 per cent. of the mineral fraction in certain of the Wowra sand and Muchea sand profiles; the proportion of sand rarely falls much below 90 per cent. The ratio of coarse to fine sand varies from about 3:1 in many types to exceptionally high figures in samples of the Wowra sand, the weighted mean, however, being about 6:1. In the Gingin clay, the sand content amounts to 50 per cent., although here the proportion of the sand fraction is quite variable. A low or very low silt content is characteristic of all soils except the alluvials where, as might be expected, it rises to as high as 25 per cent.; in the Gingin clay the mean silt content is 7 per cent. and for the remaining types 2 per cent. or less in the surface, with slightly lower values in the subsurface. In the surface samples of the Gingin clay, the clay content amounts to nearly 40 per cent., whereas in the sandy types it averages little more than 5 per cent. In the Whakea sand and Minjil sands, the mean is about 7.5, but it is considerably lower in the remaining sandy types, being virtually absent in the Wowra sand and Muchea sand. The subsoils, where encountered, of each type are distinctly heavier and generally consist of sandy loams to sandy clay loams, except in the case of the Gingin clay and Mount Pleasant sand, where distinctly heavy clays still low in silt may occur.

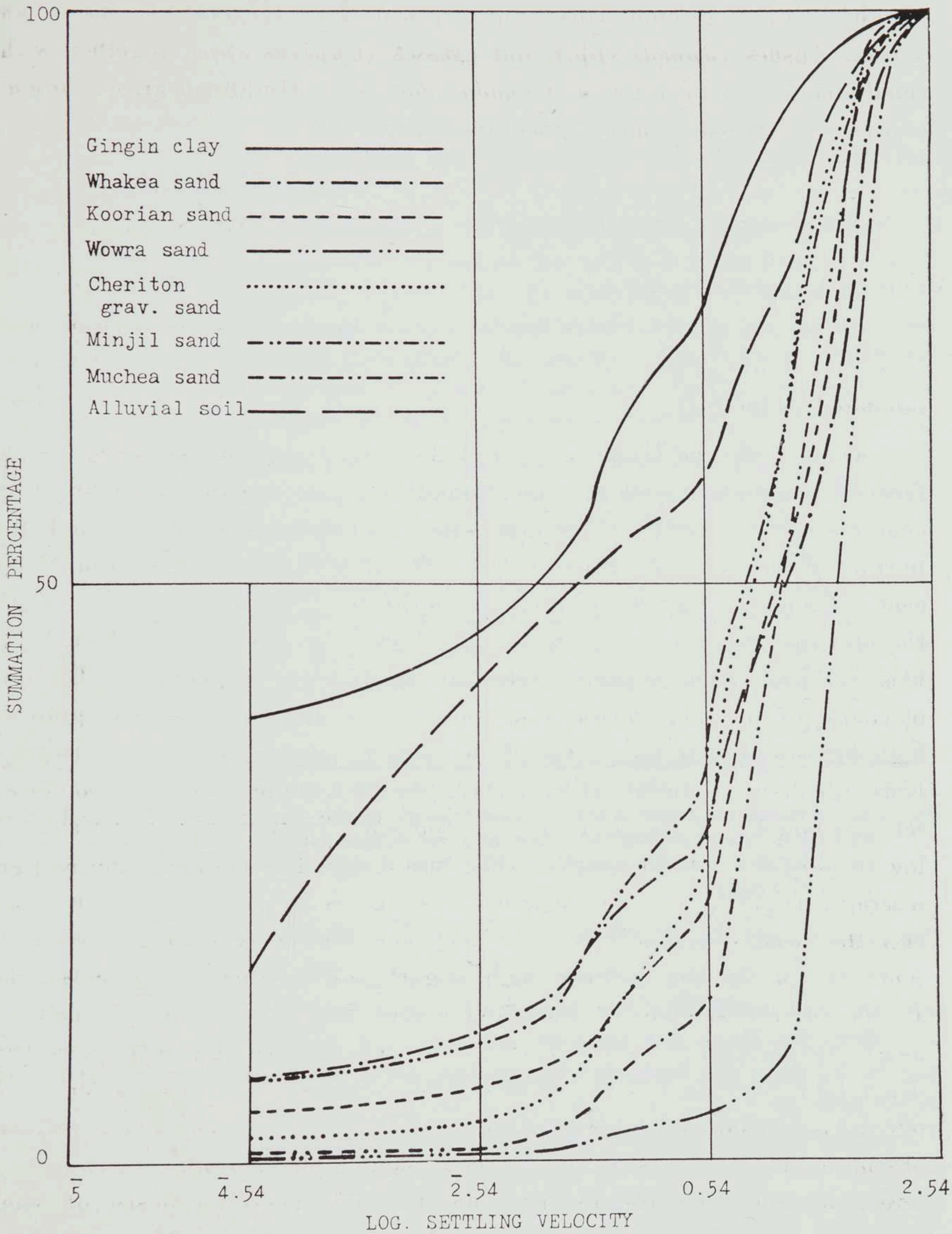

Figure 1. Summation curves illustrating the mechanical analysis of the surface samples of various types.

The general form of the mechanical analysis summation curves of the surface samples is illustrated in Fig. 1, which brings out the characteristics of the mineral portion for each type. The distribution triangle (Fig. 2) emphasises the lightness of the surface and subsurface soils, together with the heavier nature of the Gingin clay, the alluvial surface samples and the subsoils of the sandy types.

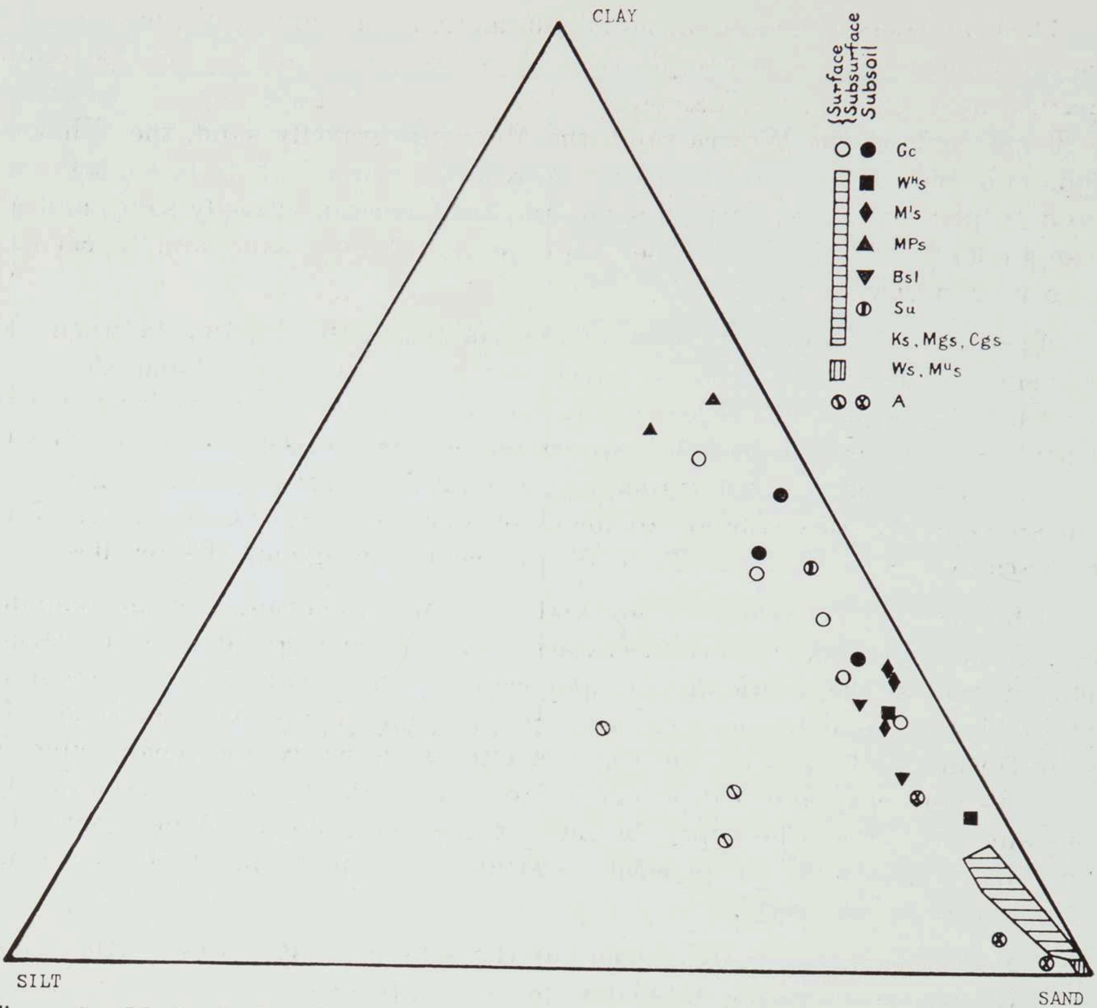

Figure 2. Mechanical analysis distribution triangle of the Gingin soils. Hatched areas and open figures represent surface and subsurface samples of the types as listed; block figures—subsoil samples. (The type designations are those employed on the soil map.)

The coarse sand fraction.[1]

Owing to the exceptionally high coarse sand content of the soils, this fraction was subdivided by means of sieves into five further fractions of which the three 2.0 mm. to 1.0 mm., 1.0 mm. to 0.5 mm., and 0.5 mm. to 0.2 mm., the limiting value of the coarse sand, are given in the tables in the text.

Apart from the Whakea sand and the Koorian sand, which show a marked variation, the sandy soils in general show a certain uniformity in the size distribution of the coarse sand grains not only in the surface samples but throughout the profiles. The variation in the proportions of the various coarse sand fractions within any type may be accounted for in a corresponding variation in the grain size in the underlying rocks. In the case of the Whakea sand where these rocks consist of the coarse-grained ferruginous sandstones a very coarse-grained sand (Sample No. 3025) results, but where they consist of greensands, a finer-grained sand (Sample No. 3022) would be expected. The Koorian sand shows also a similar variation, being coarser when formed secondarily from coarse-grained soils of the Whakea type and less coarse on the mudstones of the lower levels (compare samples Nos. 3032 and 3037). There is for all the types, with the exception of the Minjil sand and the Cheriton gravelly sand, a general tendency for the coarse sand to become finer in grain with depth.

(1) Percentage figures in this section refer only to those of the coarse sand and not to the soil as a whole.

The coarseness of grain reaches its maximum in the surface of the strongely leached Wowra sand, one sample showing 42 per cent. of the coarse sand separate over 1.0 mm. in diameter. This fraction is generally of the order of 20 per cent. in the Wowra sand, the Moorgup gravelly sand, the Whakea sand, and the yellow variation of the Koorian sand. It falls to between 6 and 10 per cent. in the Minjil sand, and the Cheriton gravelly sand, and at most amounts to only 3 or 4 per cent. in the Muchea sand and in certain areas of Koorian sand.

There is a distinct increase in the content of the fraction between 1.0 mm. and 0.5 mm. The greatest variation for any soil type, from 16 to 71 per cent. of the coarse sand, occurs in the Koorian sand and the least in the Minjil sand, where the content approximates very closely to 35 per cent. not only in the surface but throughout the profile. The Wowra sand shows a mean value for this fraction of about 60 per cent. In the remaining soils the variation is from about 30 to 50 per cent. throughout the profiles.

The fraction between 0.5 mm. and 0.2 mm., accounting for the remainder of the coarse sand, must necessarily show a corresponding wide variation; it reaches the minimum of 2 per cent. in the Wowra sand, where it is invariably low, and the maximum of 80 per cent. in the Koorian sand. It is uniformly high in the Cheriton gravelly sand, where the mean value is about 65 per cent., and Minjil sand, where again the fraction is remarkably constant throughout the type, the mean value being about 55 per cent. In the remaining sands, the general variation is again from 30-50 per cent. of the total coarse sand.

The fine sand fractions of some of the soils have also been further subdivided, the results being tabulated in the Appendix.

(2)—*Soil Reaction.**

TABLE 10.

DISTRIBUTION TABLE FOR pH VALUES OF SOIL TYPES.

Soil type.	Horizon.	pH Range.							
		4·5 to 5·0	5·0 to 5·5	5·5 to 6·0	6·0 to 6·5	6·5 to 7·0	7·0 to 7·5	7·5 to 8·0	8·0 to 8·5
Gingin Clay ...	A ...	...	...	...	1	1	...	3	...
	B–BC	...	...	...	...	...	1	1	1
Mount Pleasant Sand	A ...	...	...	1	...	...	...	...	...
	B_1 ...	...	...	...	...	1	...	...	...
	B_2 ...	...	...	...	...	...	...	1	...
Alluvial Soils and Unnamed Sands	A_1 ...	1	...	2	...	...	...	...	...
	A_3 ...	...	...	1	1	...	...	...	...
	deep A_2 or B	...	...	...	1	1	1	...	...
Remainder (sandy soils)	A_1 ...	...	4	11	10	...	...	...	...
	A_2 ...	...	4	1	19	1	...	...	...
	deep A_2 or B	...	5	...	9	2	...	...	...

* The Antimony Electrode was used throughout the course of the work for the determinations of all reaction values, the soil to water ratio being 1 to 2.5.

The reaction range for the majority of the soils for the whole area is very narrow, no less than 68 per cent. of the values for all soils falling between pH 5·5 and pH 6.5. The complete range in the surface soils is from pH4.9 in the case of the alluvial soil from the Moonda Brook flat, to pH 7.9 for the Gingin clay on Molecap Hill. The reaction of the Gingin clay soils is somewhat lower than would be expected when the high content of calcium carbonate is considered, but these low values can, however, be explained by the high buffering action of the organic matter present.

The range in values for the Gingin clay surface soils is from pH 6.3 to pH 7.9, with a slight increase in the subsurface soil from pH 7.3 to pH 8.1. For all other surface soils, excluding the alluvium, the range is from pH 5.1 to pH 6.4. There is generally a slight increase in the reaction value with depth, the range in the sub-surface being from pH 5.1 to 6.8 and in the subsoils or deeper sub-surface samples from pH 5.4 to pH 6.7. In the deep subsoil of the Mount Pleasant sand, where calcium carbonate occurs the value rises to over pH 8.0. These figures are set out in the form of a distribution table in Table 10.

TABLE 11.

REPLACEABLE BASES IN GINGIN CLAY AND WHAKEA SAND.

Soil type.	Sample number.	Depth in ins.	Soil re-action.	Clay.	Organic matter.	Milli-equivalents per 100 gm. of soil.					Percentage of total bases.			
						Ca	Mg	K	Na	Total	Ca	Mg	K	Na
			pH	%	%									
Gingin clay ...	3001	0–12	7·9	16	8·0	30·71	1·07	0·78	0·15	32·71	94	3	2	1
	3003	0–6	7·9	17	9·0	30·83	1·81	0·63	0·29	33·56	92	5	2	1
	2996	0–8	6·7	24	13·4	48·34	4·80	0·58	0·30	54·02	89	9	1	1
	3006	0–6	7·7	43	7·3	36·71	2·86	2·87	0·31	42·75	85	7	7	1
	2999	0–12	6·3	32	4·2	23·21	5·70	1·63	0·69	31·23	75	18	5	2
	3000	12–24	7·3	44	2·2	26·96	6·58	1·52	0·86	35·92	75	18	5	2
Whakea sand ...	3007	0–15	6·4	9	2·2	3·62	1·26	0·43	0·06	5·37	68	23	8	1
	3008	15–60	6·5	10	0·8	1·92	1·25	0·07	0·03	3·27	59	38	2	1
	3009	60–80	6·5	10	0·4	0·83	0·89	0·10	0·03	1·85	45	48	5	2
	3013	0–15	6·2	9	2·2	3·79	1·45	0·28	0·03	5·55	68	26	5	1
	3014	15–54	6·3	11	0·8	2·25	0·84	0·16	0·03	3·28	68	26	5	1
	3015	54–66	6·4	12	0·7	1·29	1·08	0·12	0·02	2·51	51	43	5	1

(3)—*Replaceable Bases.*

Twelve soils, representing five surface and one sub-surface sample of the Gingin clay and two profiles of the Whakea sand, have been examined for replaceable bases, the results being summarised in Table 11.

The extremely high proportion of replaceable calcium is to be noted in the Gingin clay samples and also the persistence in composition of the successive depths of profile 2999-3000. Sample 2996, although containing only 24 per cent. clay, shows a high degree of saturation, the high organic matter content contributing largely to this figure. Sodium is low in all samples examined, the average being about 1 per cent.

As would be expected from the acid nature and low clay content, the Whakea sands contain little in the way of replaceable bases. The high proportion of calcium in the surface, and its lower figure, consequent on the rise in the proportion of magnesium below, is to be noted.

(4)—*Chemical Analysis.*

(i)—*Nitrogen, Organic Carbon and Organic Matter.*

Table 12.

DISTRIBUTION TABLE FOR NITROGEN CONTENT OF GINGIN SOILS.

Soil type.		Sandy soils.										Gingin clay and surface alluvium.				
Nitrogen	%	0 to 0·01	0·01 to 0·02	0·02 to 0·03	0·03 to 0·04	0·04 to 0·05	0·05 to 0·06	0·06 to 0·07	0·07 to 0·08	0·08 to 0·09	0·09 to 0·1	0·1 to 0·2	0·2 to 0·3	0·3 to 0·4	0·4 to 0·5	0·5 to 0·6
Horizon	A_1	...	3	3	4	3	4	1	5	2	2	2	...	1	3	1
	A_2	7	8	7	6	...	1	...	...	...	...	...	...	...	...	...
	deep A_2 or B	8	4	5	1	2	...	...	...	...	...	1	2	...	...	...

With the exception of the Gingin clay and the surface of the creek alluvium in which the nitrogen rises to over 0.5 per cent., the nitrogen content is generally low and never exceeds 0.1 per cent. In the surface samples of the Gingin clay, the range is from 0.17 per cent. to 0.55 per cent., with a mean value of 0.37 per cent.; below the surface layer the nitrogen falls, the mean being 0·22 per cent. Generally there is no significance in the variation in the nitrogen content of the surface samples of the remaining types, the variation being fairly wide, though of the same order in each individual type. The range is from 0.10 per cent. for a soil of the Minjil sand near Strathalbyn to less than 0.02 per cent. in the Whakea sand to the south of Molecap Hill, and in the Wowra sand near Cleveland, with a mean value of 0.05 per cent. There is a sudden drop in the content below the surface horizon, especially in the case of the two extremely podsolised soils, the Wowra and Muchea sands, where the nitrogen practically disappears; the range here is from 0.05 per cent. in the sample of Mount Pleasant sand to 0.001 in the Wowra sand sample previously mentioned. The mean value is about 0.02 per cent. In the deeper layers of the A_2 horizon or in the subsoils, the nitrogen is even less. The nitrogen figures are summarised in the form of a distribution table in Table 12.

Organic carbon was determined on a number of representative samples from each type. It reaches its maximum in the Gingin clay, rising to nearly 8 per cent. in the surface sample from Mt. Pleasant. The range in the carbon content of the surface samples of the latter type is from 2.4 to 7.79 per cent. with a mean value of 4.86 per cent.; the mean value for the subsurface is somewhat lower, being 3.07 per cent. Exclusive of the alluvial surface sample from the Moonda flat which contains nearly 6 per cent. of carbon, the maximum value reached in the remaining soils is 1.8 per cent. in the sample of the Minjil sand from Strathalbyn, but in general the content is less than one per cent. The variation from type to type is of the same order as that for the nitrogen content. Below the surface horizon the carbon content drops considerably, the range being from 0.08 to 0.57 per cent.

The frequency distribution of the carbon to nitrogen ratios is shown in Table 13. The ratios for the Gingin clay, a typical grassland soil, fall in a restricted range, and for the other soils the usual high values and extensive range (Hosking, 1935), characteristic of woodland soils are found. In the sandy soils the organic material consists mainly of decomposing fibrous woody and root material, especially in the case of the Muchea and Wowra sands, while it is only in the Gingin clay that it can be considered to be highly "humified."

Table 13.

DISTRIBUTION TABLE OF CARBON TO NITROGEN (N = 1) RATIOS OF THE SOILS EXAMINED.

Soil type.	Horizon.	C : N Ratio.											
		8–10	10–12	12–14	14–16	16–18	18–20	20–22	22–24	24–26	26–28	28–30	30–32
Gingin Clay...	A	...	1	3	1	...	...	...	...	...	...	...	...
	AB–BC	...	...	1	1	...	...	...	...	...	...	...	...
Remaining soils. ...	A_1	...	1	4	4	7	4	4	1	1	...	...	1
	A_2	1	1	4	4	...	3	1	1	1	1	...	...
	deep A_2 and B	...	3	...	1	1	...	...	1	...	...	...	...

(ii)—*Hydrochloric Acid Extract.*

The standard hydrochloric acid extraction was made on all the soil samples and potassium and phosphoric acid determined in all the extracts. Manganese was also determined on the Gingin clay soils and certain of the Whakea sand samples.

(a)—*Potash.*—The potash content varies enormously not only from type to type, but even within the types themselves. A broad grouping of the soils into four classes based on potash content has been made as illustrated in the accompanying distribution table No. 14. The first two groups of soils derive their high potash content from the underlying rocks, which are extremely rich in glauconite.

(*i*) The Gingin clay, Mount Pleasant sand, Ballingah sandy loam, and the unnamed sand, constitute the first class, in which no sample contains less than 0.2 per cent., but may contain as much as 4 per cent. In the Gingin clay the content varies in the surface from 0.3 per cent. in the shallow soil at One Tree Hill to over 3.0 per cent. in the deep soil from below Ginginup, the mean value being about 1.3 per cent. The proportion of potash in the subsoil is of the same order as that in the surface. The highest percentage recorded is 4.38 per cent. in the deep subsoil of the Ballingah sandy loam associated with the glauconitic outcrops.

(*ii*) The Minjil sand has been placed in a class by itself since it forms an overlap between classes (i) and (iii). In the surface the potash varies from 0.03 per cent. in the yellower varieties to over 0.6 per cent. in the browner varieties. The potash content of the surface and subsurface is similar, but it generally rises considerably in the clay subsoil.

(*iii*) The Whakea sand, Koorian sand and the two alluvial profiles examined fall into a third class where the potash content in the surface varies from 0.02 per cent. to 0.2 per cent. The variation in the A_2 horizon is of exactly the same order except in the alluvial soil from the Wowra plains which is practically devoid of potash, and really belongs to the following class.

In this class, the Koorian sand and alluvial soils fall entirely in the lower portion of the range between 0.02 and 0.04 per cent. The weakly podsolised nature of these soils would account for the lower content of potash, considering the material over which they lie.

(*iv*) With the exception of the Moorgup sand, the remaining soils are very highly leached, a fact which would account for the very low potash content, which is never greater than 0.02 per cent. In the Wowra and Muchea sands potash is virtually absent.

(b)—*Phosphoric acid.*—The phosphoric acid content varies from type to type and within the types themselves, the content being of the same order as for the potash. A grouping into four classes with the same limits is again possible, as illustrated in Table 14, and although in general the order of the soils is the same, a slight re-arrangement within the groups is necessary.

This high phosphate content of certain classes is definitely associated either with the coprolite or phosphatic beds at the base of the chalk, or to a lesser extent with the glauconitic beds rich in dufrenite.

(*i*) The Gingin clay and Ballingah sandy loam constitute the first class. The phosphoric acid varies in the surface samples from 0.2 per cent. at One Tree Hill to the extraordinarily high figure of 2.2 per cent. in the outcrop near Cleveland, with a mean of close on 1 per cent., and again there is only a slight variation in the content below the surface. In the Ballingah sandy loam profile, in the surface, the content is 0.8, and this rises abruptly at 12 inches to 1.5 per cent., and in the subsoil to over 2.0 per cent. phosphoric acid.

(*ii*) The Mount Pleasant sand falls into the second class with the Minjil sand where the range in the surface is from 0.02 to 0.2 per cent. phosphoric acid, the same as in the following class, but distinguished by an increase in the subsoil to over 0.4 per cent.

(*iii*) The Whakea sand, the unnamed sand, and the Moorgup gravelly sand constitute the third class with amounts varying from .01-.08 per cent. phosphoric acid. There is again little variation with depth.

(*iv*) The remaining soils constitute the final class as very deficient in phosphoric acid. The one alluvial soil in the surface does show a relatively high proportion of 0.06 per cent. phosphoric acid, but has been included with this class, since below the surface layer the phosphate amounts to little more than a mere trace, which is characteristic of most of these leached soils.

Table 14.

DISTRIBUTION TABLE FOR POTASH AND PHOSPHATE PERCENTAGE FOR THE GINGIN SOIL TYPES.

—	Soil Type.	Horizon.	Class 4.		Class 2.																				
					Class 3.									Class 1.											
			0·01	·01–·02	·02–·03	·03–·04	·04–·05	·05–·06	·06–·07	·07–·08	·08–·09	·09–0·1	0·1–0·2	0·2–0·3	0·3–0·4	0·4–0·5	0·5–0·6	0·6–0·7	0·7–0·8	0·8–0·9	0·9–1·0	1·0–2·0	2·0–3·0	3·0–4·0	4·0–5·0
Potash K_2O	Gingin clay Mt. Pleasant sand Ballingah sandy loam Unnamed sand	A...	...	...	...	...	...	...	...	...	...	...	...	...	1	1	2	...	1	...	...	2	...	1	...
		Shallow B ...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1	...	...	...	2	...	2	...
		Deep B	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	1
	Minjil sand	A_1	...	...	...	1	1	1	...	...	...	...	1	...	...	...	...	1	...	...	...	...	...	...	...
		A_2	...	...	...	...	2	1	..	...	...	...	1	...	...	...	...	...	...	1	...	...	...	...	...
		B	...	...	...	1	...	1	...	...	...	...	...	...	1	...	...	...	...	1	1	...	...	...	...
	Whakea sand Koorian sand Alluvial soils	A_1	...	...	4	3	1	2	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...
		A_2	1	...	4	3	1	...	1	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...
		Deep A_2 ...	1	...	1	3	2	...	1	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...
	Moorgup gravelly sand Cheriton gravelly sand Wowra sand Muchea sand	A_1	4	6	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		A_2	5	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Deep A_2 ...	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Phosphate P_2O_5	Gingin clay Ballingah sandy loam	A	...	...	...	...	...	...	...	...	...	...	...	1	1	...	1	...	1	...	...	1	1	...	...
		Shallow B ...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	...	...	...	...	...	2	...	...	...
		Deep B	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...
	Minjil sand Mt. Pleasant sand	A_1	...	1	1	...	1	...	1	...	...	1	1	...	...	...	...	...	...	...	...	...	...	...	...
		A_2 or shallow B	...	...	3	...	...	...	...	...	1	...	...	1	...	...	...	...	...	...	...	...	...	...	...
		B	...	...	1	1	1	...	...	...	...	1	1	...	...	1	...	...	...	...	...	...	...	...	...
	Whakea sand Unnamed sand Moorgup sand	A_1	...	...	1	1	2	1	2	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		A_2	...	...	1	1	1	2	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Deep A_2 or B ...	...	...	1	...	2	2	1	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Alluvial soils Koorian sand Wowra sand Cheriton gravelly sand Muchea sand	A_1	9	4	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		A_2	11	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
		Deep A_2 ...	5	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

(c) *Manganese.*—Manganese has been determined in the Gingin clay and some of the Whakea sand samples. The manganese content (entered in the tables as the percentage of the oxide Mn_3O_4) of these soils is very low indeed. In the Gingin clay surface samples, the mean value is 0.016 per cent. Mn_3O_4, the range being from 0.007 to 0.21 per cent., and in the surface it is slightly lower, the mean value there being about 0.01 per cent. In the Whakea sands it is only present in the merest traces, the mean for all the samples examined being less than 0.002 per cent.

(iii)—*Lead.*

Owing to a suspicion that lead-poisoning might be the cause of the ataxial condition affecting stock at Gingin, a determination of this element was made on three of the Gingin clay samples (Numbers 2996, 2999 and 3006), and two of the Whakea sands (Numbers 3007 and 3013), together with soils (Numbers 3081 and 3085) from the unaffected country, for comparisons. Blanks on the materials used were run at the same time. The method used was that of Bertrand and Okada (1933) modified to suit the local soils. Although 200 gm. samples of the soils were used, no trace of lead, determinable by macro-chemical methods, was found either in the affected or non-affected soils.

V.—SOILS FROM THE UNAFFECTED AREAS.

A brief reconnaissance of the soils of the coastal plain which appear to possess certain inhibiting and curative properties was made in the vicinity of Glencoe homestead. Rainfall figures given in Table 1 for Beermullah Lake show that the climatic conditions here are practically identical with those in the Gingin areas. The underlying rocks consist mainly of hard compact limestone containing small mollusc shells of presumably Tertiary age. A soft friable limestone, possibly an aeolian formation, was also observed. Some of the limestone associated with the red sands or sandy loams near Glencoe is of a crustal nature and resembles a secondary formation rather than a rock *in situ.* Ridges of a ferruginous nature are often encountered outcropping throughout the area.

The country is gently rolling with only low hills and is drained by the Gingin Brook and its tributary, the Mungala Brook. To the north-east of Glencoe and at the headwaters of the Mungala Brook the country examined is known as the Beermullah Plains. These plains are distinct in soil and vegetation characteristics from the coastal plain, the Glencoe and the Gingin country.

The soils of Glencoe and Beermullah may be divided into five types:—(i) a grey brown to red brown or chocolate sand to sandy loam; (ii) a series of red or brown to yellow sands; (iii) sandy soils carrying a jam

(*Acacia acuminata*) and York Gum (*Eucalyptus foecunda* var. *loxophleba*) association; (iv) black swampy clays, and (v) the Muchea sand already described.

(i) The profile of this type generally consists of—

0-12in.	Grey brown to red brown sandy loam;
12-24in.	Red brown to brown, grey mottled, sandy clay;
24-36in.	Brown, green mottled, heavy clay;
36in.	Limestone.

The type occurs fairly extensively in the area covered. The surface, although generally of a brownish shade, tinged grey with the little organic matter it contains, has often a distinct chocolate shade, especially where it has been under crop. To a depth of 12 inches it varies in texture from a sand to a sandy loam and overlies a red brown, mottled grey sandy clay to heavy clay. At 24 inches, this clay subsoil becomes even heavier, except where mixed with decomposing rock material, when the sandy clay texture persists; it still retains its brownish colour although the mottling changing to a distinct green becomes far more pronounced. The profile directly overlies the limestone, and $CaCO_3$ is often present in the lower layers of the soil which is seldom more than 3 feet deep. Limestone is often encountered on the surface, and ridges of ferruginous sandstone are common throughout this country. In the vicinity of these ferruginous outcrops, stone is frequently found in the profile.

The soil carries a vegetation of marri (*Eucalyptus calophylla*), flooded gum (*E. rudis*), tea-trees (*Melaleuca* spp.), blackboys (*Xanthorrhoea* spp.) and wattles (*Acacia* spp.).

(ii) A series of sands varying in colour from yellow or brown to red occur frequently throughout the Glencoe area, the common profile consisting of—

0-12in.	Grey, yellow, brown or red sand containing little organic matter;
12-30in.	Yellow, brown or red sand;
30-36in.	Yellow, red mottled, sandy loam;
36-42in.	Brown, green mottled, sandy clay loam.

The depth of the sand varies somewhat, but the change to the underlying sandy loam is characterised by the appearance of the red ferruginous mottling which increases to a depth of 36 inches. At this depth the texture becomes somewhat heavier and the soil becomes browner, while the mottling gradually changes to a distinct green, pointing, as in the first soil, to the presence of reducing agencies. At 24 inches small ferruginous sandstone fragments are encountered which increase in size and abundance till 30 inches is reached, thereafter they decrease again with depth. Scattered limestone is frequently found over the surface.

The vegetation is somewhat similar to that of the Muchea sand.

(iii) Near Lakes Bootine and Beermullah, sandy soils are found, characterised not only by the growth of jam (*Acacia acuminata*) and York gum (*E. foecunda* var. *loxophleba*), but also by the occurrence of a hard pan layer at about 14 inches.

The profile in general consists of:—

0-8″ yellow red to brown sand.
8-14″ red brown to greenish grey sandy loam.
14″+ hardpan layer.

The surface, varying in depth from 6 to 11 inches, overlies a shallow layer, never more than about 6 inches, of a red brown to greenish-grey mottled sandy loam, below which at about 12 to 14 inches there occurs a definite hardpan layer, seldom penetrable to more than a few inches with ordinary sampling tools. In one case (sample No. 3087) the hardpan was penetrated to a depth of 30 inches. This layer consisted of a red to yellow clay with sand pockets of much the same colour throughout.

(iv) A fairly heavy black crumbly soil is often found in some of the smaller depressions. In winter these soils are distinctly swampy, but like the Gingin clay they dry out in the summer and thus suffer considerable contraction, resulting in the formation of a network of deep cracks throughout. It consists of a uniform black clay of a varying thickness, overlying limestone with fragments of this material scattered through the profile and over the surface. Tea trees, which form a considerable thicket, especially round the borders, together with reeds and rushes, are practically the only form of vegetation.

(v) The Muchea sand has already been described on page 92.

The mechanical analyses and chemical data for these soils, excluding those for the Muchea sand, are given in Tables 15 and 16.

Table 15.

MECHANICAL ANALYSES AND CHEMICAL DATA OF SOILS FROM GLENCOE STATION.

Soil type	Grey brown to red brown sandy loam.									Black clay.
Locality	North-west from Glencoe homestead.						East of homestead.			Near Mungala Brook.
Sample number	3081	3082	3083	3572	3573	3574	3578	3579	3580	3576
Depth in inches	0–15	15–24	24–36	0–9	9–24	24–30	0–10	10–30	30–42	0–12
Horizon	A	B	BC	A	B	BC	A	B	BC	A
	%	%	%	%	%	%	%	%	%	%
Stone	1	1	2	...	1	19	9	8	17	4
Fine gravel, 3 mm.—2 mm.	...	...	...	...	...	5	3	5	8	...
Coarse Sand										
2·0 mm.—1·0 mm.	0·8	0·5	1·2	0·5	0·3	0·5	5·5	1·8	3·5	0·6
1·0 mm.—0·5 mm.	10·4	7·3	5·2	14·9	7·9	5·8	10·0	3·6	4·4	5·5
0·5 mm.—0·2 mm.	33·6	25·3	16·5	46·8	24·4	16·8	28·1	11·1	9·4	18·3
Total	44·8	33·1	22·9	62·2	32·6	23·1	43·6	16·5	17·3	24·4
Fine sand	32·4	24·0	15·5	25·7	16·1	11·4	24·7	12·6	18·5	18·0
Silt	6·0	5·0	6·3	2·9	3·9	4·8	7·8	9·9	15·3	6·7
Clay	13·4	32·5	44·5	6·8	40·0	44·6	18·8	49·6	34·9	42·5
Loss on acid treatment ...	0·8	0·9	1·0	0·5	1·3	9·1	1·3	2·1	2·1	1·9
Moisture	2·3	5·7	9·4	1·0	7·4	8·8	3·7	10·9	13·1	7·2
Calcium carbonate ... $CaCO_3$	...	...	...	...	...	7·82	...	...	...	0·13
Phosphoric acid ... P_2O_5	0·021	0·014	0·009	0·014	0·011	0·013	0·050	0·011	0·005	0·015
Potash ... ... K_2O	0·402	0·887	1·243	0·116	0·779	0·884	0·224	0·454	0·402	0·606
Nitrogen ... ... N	0·067	0·053	0·044	0·047	0·043	0·063	0·114	0·046	0·038	0·055
Organic carbon ... C	1·15	0·65	0·38	...	...	...	...	...	...	...
Carbon/Nitrogen/ratio... C/N	17·1	12·3	8·5	...	...	...	...	...	...	...
Soil reaction ... ... pH	6·7	7·0	7·1	6·9	7·0	8·0	7·0	7·7	7·7	7·9

Table 16.

MECHANICAL ANALYSES AND CHEMICAL DATA OF SOILS FROM THE VICINITY OF GLENCOE STATION.

Soil type	Red brown sand.				Hardpan soils.					
Locality	Glencoe.				East of Lake Bootine.			Near Lake Beermullah.		
Sample number	3582	3583	3584	3585	3085	3086	3087	3587	3588	3589
Depth in inches	0–12	12–28	28–36	36–42	0–8	8–14	14–30	0–11	11–14	14–16
Horizon	A_1	A_2	B		A_1	A_2	B_1	A_1	A_2	B_1
	%	%	%	%	%	%	%	%	%	%
Stone	...	...	6	2	1	2	2	4	2	10
Fine gravel, 3 mm.—2 mm.	...	2	2	2	2	1	1	2	1	2
Coarse sand 2·0 mm.—1·0 mm.	1·6	1·5	1·3	1·2	1·9	2·0	1·7	0·8	0·6	...
1·0 mm.—0·5 mm.	10·5	8·1	9·8	9·5	12·1	12·4	10·6	11·1	8·0	...
0·5 mm.—0·2 mm.	41·1	36·0	35·8	34·5	37·6	34·2	27·8	45·1	35·7	...
Total	53·2	45·6	46·9	45·2	51·6	48·6	40·1	57·0	44·3	...
Fine sand	39·3	44·8	31·9	25·5	29·8	27·1	24·1	22·2	17·9	...
Silt	1·9	1·8	2·7	2·3	7·7	7·2	5·6	6·8	5·8	...
Clay	4·4	6·4	17·1	23·6	8·7	14·2	26·7	12·0	28·0	...
Loss on acid treatment	0·3	0·2	0·4	0·4	0·2	0·2	0·2	0·3	0·9	...
Moisture	0·4	0·5	1·6	3·3	1·3	2·1	4·0	1·2	3·1	...
Phosphoric acid ... P_2O_5	0·017	0·017	0·016	0·007	0·008	0·004	0·003	0·011	0·007	0·004
Potash ... K_2O	0·018	0·029	0·062	0·071	0·094	0·090	0·123	0·127	0·313	0·766
Nitrogen ... N	0·028	0·014	0·016	0·010	0·061	0·048	0·040	0·064	0·056	0·032
Organic carbon ... C	...	...	...	...	0·62	0·40	0·29	...	...	...
Carbon/nitrogen ratio ... C/N	...	...	...	...	10·2	8·3	7·2	...	...	...
Soil reaction ... pH	6·4	6·4	6·6	7·0	5·4	5·3	5·8	6·0	6·8	7·4

Except in the heavy black soil the sand fractions constitute about 80 per cent. of the mineral matter of the surface layers, varying from 72 per cent. in the profile 3578 to over 90 per cent. in the brown sandy soil 3582. Unlike the Gingin soils, the coarse sand does not preponderate to the same extent, the ratio of coarse to fine sand rarely exceeding about 2:1 throughout the profile. In the sandy loams this ratio may become narrower with depth. Silt is uniformly low throughout the profile, varying from 2 to 8 per cent., the single exception being sample No. 3580. Clay, excepting in the swampy soil, is always low in the surface, but increases sharply in the subsoil in all the profiles.

With the exception of the swampy type, the soils vary in their reaction from distinctly acid to neutral in the surface, but with the advent of the limestone, change to alkaline in the subsoils.

The nitrogen content varies in the surface from 0.114 per cent. in sample No. 3081 to 0.02 per cent. in the sand No. 3582, with a mean of about 0.06 per cent. The highest content, varying from 0.047 to 0.114 per cent., occurs in the soils of the first type, and the lowest in the second type described above. The soil characterised by the jam (*Acacia acuminata*) contain about 0.06 per cent. There is a decrease in the subsurface to a mean of 0.04 per cent. with only a further slight diminution in the subsoils.

Phosphoric acid is highest in the first type described where it varies from 0.014 to 0.05 per cent. in the surface. The complete range for all the surface soils examined is from less than 0.01 in the jam soils to 0.05 of the former type with a general mean of 0.03 per cent. The mean falls to 0.02 per cent. in the subsurface and again is only slightly less in the subsoil.

Potash is generally high except in the red brown sand where it is less than 0.02 per cent. throughout the profile. In the remaining soils it varies in the surface from slightly less than 0.1 per cent. in the jam soil to 0.6 per cent. in the swampy soil, the mean being about 0.26 per cent. There is a distinct increase in the subsurface and subsoil, sample No. 3083 showing over 1.2 per cent.

VI.—RELATION OF SOIL TYPE TO AGRICULTURAL PRODUCTION AND DEVELOPMENT.

1.—*Enzootic Ataxia in Lambs.*

The presence of the abnormal condition for which Bennetts (1932) has adopted the term enzootic ataxia, affecting young lambs in the Gingin district, has been recognised in Western Australia during the past 20 years. According to Bennetts (1932) this disease is similar to conditions in lambs described as occurring in other countries, notably in *Peru, Sweden* and the *British Isles.*

It appears from information supplied by Bennetts that the disease occurs over the whole of the area at Gingin underlain by Cretaceous rocks, quite irrespective of soil type. The disease is also apparent in those parts of the coastal plain watered by the Gingin Brook. Country adjacent to the Moore River, whose head waters are in the granite and gneiss of the Darling Plateau, is apparently unaffected. At the junction of these two streams there are two adjacent farms, the one watered by the Moore River being unaffected and the other watered by the Gingin Brook being affected by the disease. The Beermullah Plains and other country associated with the Mungala Brook are reported to be sound.

Recent investigations show that the disease occurs in several other districts in Western Australia, and while most commonly met with on Cretaceous country, is not confined to it. Several properties at Mt. Barker, on granitic formations, are affected and the disease has been encountered at Rosa Brook, where no Cretaceous or other limestone formations occur. Present data indicate that portions of the South-West coastal country are also affected, as the disease occurs in the vicinity of Busselton and Yallingup.

(2)—*Incidence of Depraved Appetite in Stock.*

This area is one of the few in Western Australia in which bone-chewing and carrion-eating in cattle rarely occur. Removal of stock to other districts arrests the development of enzootic ataxia but generally induces depraved appetite.

(3)—*Agricultural Production.*

In the virgin state the Gingin clay was practically treeless, though well grassed. It now carries a good pasture of clovers, medics and grasses and is never set down to crop.

The Whakea sand is cultivated for rye, oats and lupins, and carries grasses in pasture years. The lupins of the district are noted for their excellent condition and quality, and exercise a marked influence in building up the soil in nitrogen and humus, thus causing a darkening in the surface layer. The response of the Whakea sand to superphosphate is reported to be slight.

The Koorian sand carries very poor pasture, but in the more productive areas is cultivated in rotation with pastures. The Minjil sand, on the other hand, carries good pasture and is used for cultivated crops.

The Cheriton Gravelly sand, Wowra and Muchea sands are of very low fertility and are generally left in the virgin state. The former has been used for orchard purposes but the trees are returning a very low yield at present. The soils of the alluvium provide rich summer pastures and are being further developed by drainage.